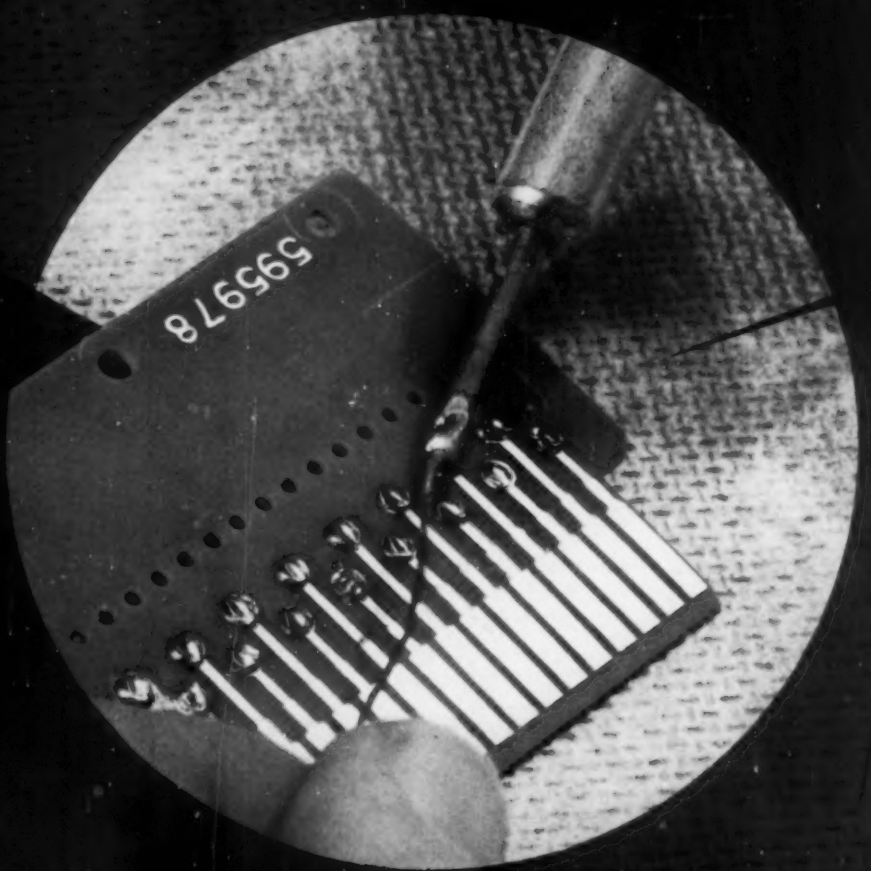
PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS · MARCH 6, 1961



how to choose a soft solder...

SEE PAGE 39

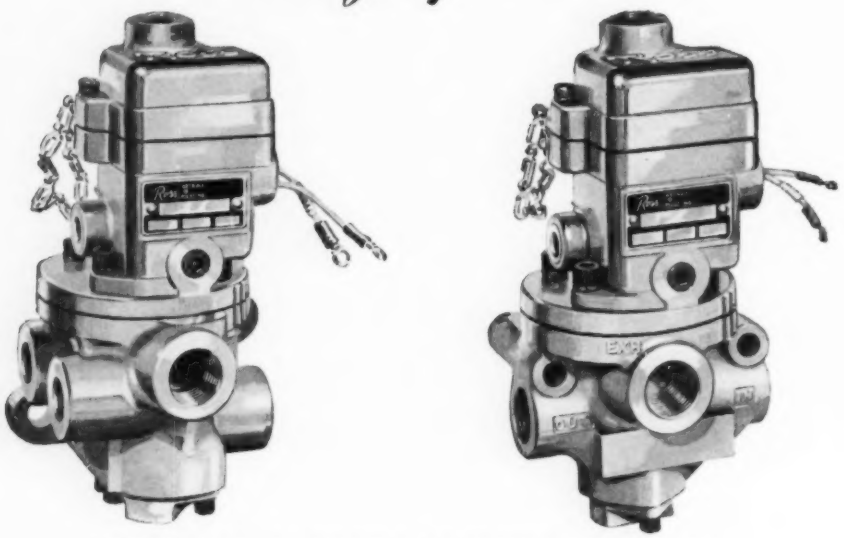
WHEN LINKAGES NEED HARMONIC ANALYSIS . . . page 47
HOW PRACTICAL IS 400-CYCLE POWER TODAY? . . . page 54
SCIENCE SPEEDUP—A TECHNOLOGICAL CRISIS . . . page 56

THANK YOU . . .

for your enthusiastic response to this announcement. Because it has been viewed as an important advance in valve development, we reprint this news for those who missed its first appearance.

Ross

Proudly presents



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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS

March 6, 1961 Vol. 32, No. 10

FEATURED:

DEPARTMENTS:

INTERESTING TO NOTE 3
COMING NEXT WEEK 4
WHAT'S NEW IN RESEARCH 6
DEVELOPMENTS TO WATCH 8
FROM WASHINGTON 12
THE ENGINEERING WEEK 15
INDUSTRIAL DESIGN 24
READER TO EDITOR 24
MEETINGS 29
WHY NOT R&D 32
HORIZONS 37
PRODUCT DESIGNS 51
SIGNIFICANT COMPONENTS 62
DESIGN LITERATURE 74
ADVERTISERS INDEX 82
READER SERVICE CARDS 83

CHOOSING THE RIGHT SOFT SOLDER ALLOY . . . H H Manko
A comparison of 28 basic types shows which is best for your job..... 39

WHEN LINKAGES NEED HARMONIC ANALYSIS . . . F Freudenstein and K Mohan
Concise table for designing efficient crank-and-rocker mechanisms..... 47

HOW PRACTICAL IS 400-CYCLE POWER TODAY? . . . F E Hall
It's expensive now, but it won't be much longer; here's why..... 54

THE ACCELERATION OF SCIENCE . . . D J de Solla Price
A noted science historian's startling views on a major crisis..... 56

EIGHT PAPER-FEED MECHANISMS . . . F W Wood Jr and V Huffines
These designs keep paper moving, whether in sheets or strip..... 60

FIELDS OF INTEREST REPRESENTED IN DEPARTMENTS:

MATERIALS:
New light on metal strength and hardness..... 6
Two new lubes ready, another coming..... 8
High-strength wire goes commercial..... 9
Structural plastic is easy molding..... 17
Press-on tape damps resonant vibration in thin sheetmetal..... 62
Fluid silicone rubber cures in 24 hr at room temperature..... 62

MECHANICAL:
Aluminum seals give higher vacuum..... 8
Sintered-bronze bearings to offer lower friction coefficients..... 8
Hydraulic suspension system used on new tractor..... 16
Spacer-type coupling corrects up to 6° misalignment..... 62

ELECTRICAL:
Selecting components for high ambient pressures..... 6
Magnet wire improved by annealability control..... 9
New standards nearing for printed circuit boards..... 9

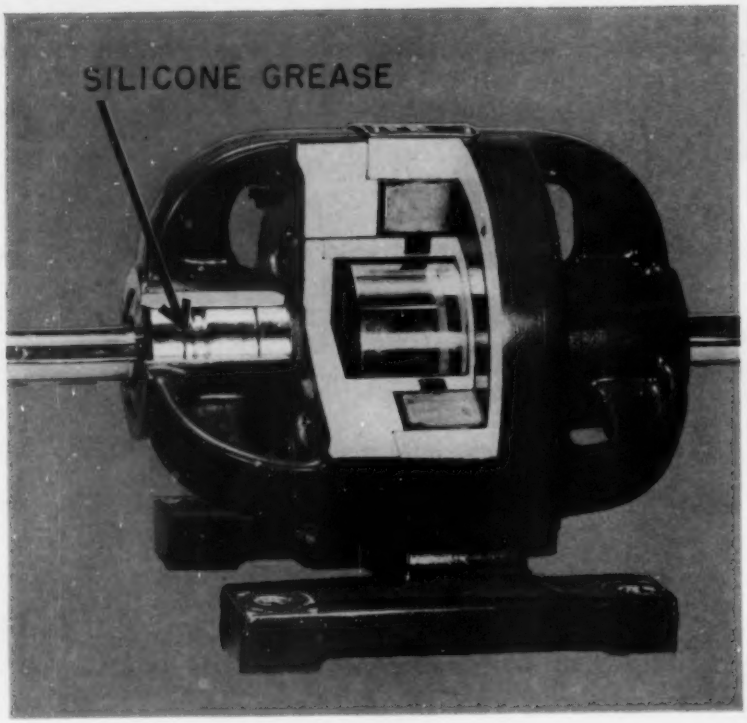
TESTING:
Helium isotope for colder cryogenic research..... 6
Analyzer writes bearing record..... 15

PRODUCTS DESIGN:
Gear mounted on shaft hydraulically..... 51
Photocell adjusts magnetic clutch..... 52
Dual clutches speed response of missile controls..... 53

GENERAL:
Automatic photocopier gives dry copies fast..... 9
Small business to get more military contracts..... 12

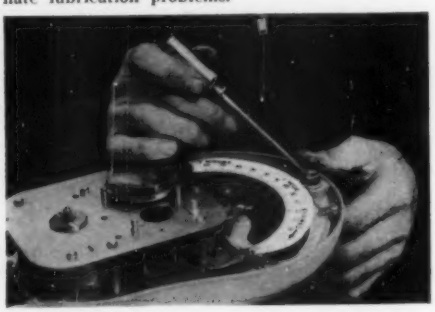
SILICONE NEWS from Dow Corning

Lubricants That Last



LONG SHELF LIFE—Lubricated with silicones, timing devices, made by Appliance Manufacturing Co., for automatic dryers, operate accurately and quietly after extended storage.

HEAT & COLD—Silicone lubricants prevent locks on parking meters from freezing up . . . eliminate lubrication problems.

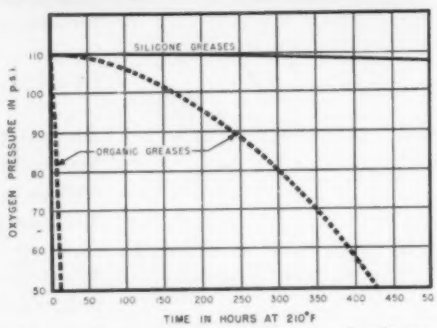


Silicone Lubricants Beat the Heat... Won't Oxidize In Service or On Shelf

Typical of the new designs made trouble-free with the aid of heat-stable Dow Corning Silicones is the magnetic clutch shown above. Manufactured by Vickers Incorporated, Electric Products Division, Sperry Rand Corp., St. Louis, Mo., this clutch can slip continuously, and therefore, must dissipate heat . . . heat that is conducted to the ball bearings. To lubricate these bearings, Dow Corning silicone grease was specified because it doesn't thin out and run away when temperatures skyrocket. Nonoxidizing, silicone grease remains operable for many years despite continuous temperatures of 450 F and higher.

YEAR 'ROUND LUBRICATION . . . INDOORS AND OUT. Silicone lubricants withstand both cold and heat . . . give all-year lubricity to outdoor mechanisms such as parking meters. Viscosity of silicones remains virtually constant down to —100 F . . . won't stiffen. Silicone lubricants also provide excellent shelf life, thus assuring instant starts for equipment left in storage for extended periods.

If your special design encounters any of the conditions just mentioned—high heat, cold, extended shelf life, weathering — a Dow Corning silicone grease will probably end your lubricating problems on metal, plastic or rubber parts. Send for literature, or outline your lubrication problem on your letterhead and we'll send you a free sample. Be your own judge. Address Dept. 7215 today.



The excellent oxidation resistance of silicone lubricants is shown above. After 500 hours of exposure to oxygen under 110 psi at 210 F, with a brass catalyst, silicone lubricants caused a pressure drop of only 1.5 pounds.

The nearest Dow Corning office is your number one source for information and technical service on silicones.

first in silicones

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MIDLAND, MICHIGAN

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INTERESTING TO NOTE

On our cover—soldering, an old art that is a most important joining technique today. The hand-soldering operation shown is but one of several distinct methods for making soft-solder joints in industrial equipment. A modern IBM data-processing system, for example, may have as many as 500,000 soldered connections, obviously requiring a wide variety of techniques. As discussed in the article "How to Choose the Right Soft Solder Alloy," p 39, careful design must precede production of any soldered joint. Author Howard Manko points out, "I would rather see people use other methods of joining than to try and solder a poorly designed joint." His article is intended to help designers specify the best solder, and is a sequel to an earlier article, on fluxes (*PE— June 13, '60, p 43*).

Found—One Early Escapement Mechanism

Few TV dectectives solve their cases in a library. For a science historian, on the other hand, an old book may be the only clue to a century-old mystery. In his forthcoming publication, *Science Since Babylon*, Derek J. de Solla Price presents an excellent example of a modern science historian at work. (A chapter from Dr Price's book is abstracted on page 56.)

One of Dr Price's interests is the history of early clock and compass mechanisms. It has long been the practice of those writing on early clockworks to start by describing the sundials and water clocks of early Eastern civilizations, then jump abruptly to intricate geared clocks with delicate escapement mechanisms. Dr Price decided to find out the mysterious origin of the clock escapement, one of the few major inventions that remained completely anonymous and unaccounted for. He knew that early clock mechanisms were built in China to duplicate the motions of the heavens, so he visited a colleague at Cambridge, who was famous for his work on Chinese science.

During his literary search, Price found that a book written by Su Sung in 1092 contained many technical diagrams of a planetarium-like object Su Sung constructed in 1088. For four months, Price and his associates translated the ancient Chinese document.

According to Dr Price, Su Sung's device, called an astronomical clocktower, stood some 30 feet high, with another 10 feet of observing instruments mounted on a platform on top. Concealed within the housing was a giant waterwheel fed by a carefully controlled flow that dripped at a steady rate, filling the buckets on the wheel slowly. Each quarter hour, the wheel became so loaded that it tripped its escapement mechanism.

On the tower top, an armillary sphere—a device fitted

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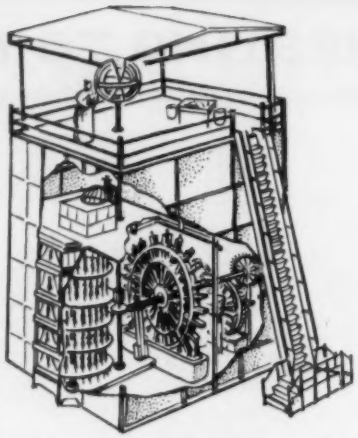
with rings representing important positions of the celestial sphere—was turned automatically to keep pace with the moving heavens. In a chamber below, a marked starglobe also rotated automatically so astronomers could follow the risings and settings of stars and planets without going outside.



On the front of the clocktower was a miniature pagoda with a series of doors one above the other. At appointed times, whenever the escapement tripped, these doors would open and little manikins would appear, holding tablets marked with the hours of the day and night, ringing little bells, clashing cymbals and sounding gongs. For all the complexity of its externals, the Su Sung clocktower was a comparatively simple mechanism. The big waterwheel needed only a simple pair of gears to connect it to the rest of the paraphernalia, which in turn needed only the most elementary mechanical levers and such devices to produce its effects. Only the escapement mechanism was totally unexpected and refined. The American researchers managed to trace the invention of this form of water-and-lever escapement back to one of the many astronomical clocks built in 725 by the Tantric monk I-Hsing and his engineering collaborator Liang Ling-Tsan.

Dr Price had found a missing link in the chain of historical events from the sundial and shadow stick to the intricate timing mechanisms of today.

—Benedict A Leerburger Jr

SIDELIGHT

When the cold wave hit the East last month, bedraggled commuters were stranded on platforms and in trains when switches froze or brakes wouldn't work. Philadelphia's new subway trains also ran into brake trouble, somewhat embarrassingly so, since the brakes on the 1908-model trains they were replacing had been working perfectly.

"Of course, we'll work the bugs out of these new brakes," a transit engineer noted. But he wouldn't deny that the 1908-vintage brakes worked better in this pinch than the new ones. The new brakes, on 270 stainless-steel self-propelled cars, are "dynamic electrical braking" systems in which the subway trains are slowed by an operation that resembles reversing the motors. When the train slows to around 4 mph, mechanical brakes take over and bring it to a complete halt. High winds, subzero temperatures, and blowing snow foiled the new braking systems. A thin film of ice built up on the steel train wheels. When the train operator put on the brakes, the subway trains continued to slide along the rails. In some cases, they missed the subway stations.

The old cars—there once were 315 of them—were equipped with a simple mechanical braking system, which generated more friction than the new ones. Brake shoes merely clamped onto the wheel rims—and the train stopped.

This wasn't the first time this had happened to the $25-million trains. When this first happened in December, engineers for the City of Philadelphia figured out a way to use the new brakes so that such icing would be prevented; train operators were told to apply the mechanical brakes once or twice between stations to melt the thin film of ice. During January's snowstorm accompanied by lower temperatures the method was not fully successful.

"We'll just have to figure something else out," an engineer said.

NEXT WEEK IN PRODUCT ENGINEERING

. . . **New Equations Simplify Pin Measurement of Gears**

These explicit formulas are for calculating over-pin measurements of ideal tooth forms. They will also establish over-pin measurements for desired variations of tooth or space thickness.

. . . **For Stronger, Tougher Metal-powder Parts**

Sintered iron-powders with densities over 90% can do jobs formerly restricted to the wrought or cast metal.

. . . **How to Design Simple Optical Systems**

A review of the fundamentals, plus a rundown on typical components and how to use them.

. . . **What Size Drive Rod Between Vibrator and Test Piece?**

This easy-to-use nomograph gives the answer.

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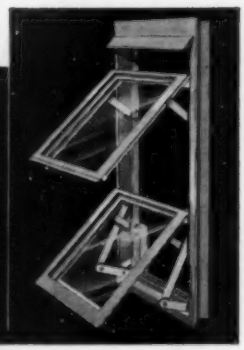

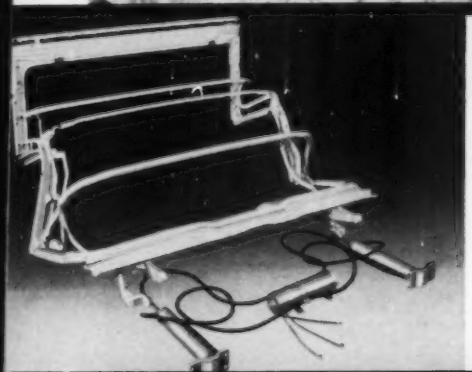

Dura Actuators raise and lower head and foot sections of Dura Select-A-Rest adjustable bed.

Dura Actuators raise and lower convertible tops, car windows, rear decks, etc.

Dura Actuators operate marine clutch and transmission mechanisms, power steering, and can tilt and lower large outboards.

Those "magic muscles" for opening, closing, lifting, lowering, pushing, pulling, turning, starting, stopping things—the team at Dura has more experience in them than any other team in the country, maybe in the world.

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WHAT'S HAPPENING IN RESEARCH . . .

Selecting components for high ambient pressures

To find suitable components for use in underwater equipment, the Navy has a major component-testing program underway. Results so far have been both useful and surprising.

• At hydrostatic pressures in the 10,000-psi range, C. L. Buchanan and M. Flato of Naval Research Labs say, potted semiconductor devices stand up well; but hermetically sealed units fail. The reason: crushing of the container and subsequent mechanical damage.

• Permeability of powdered-iron toroidal cores increases. The increase is not large—about 8%; but it is not completely reversible. Even after return to atmospheric pressure, about 2% of the increase remains.

• Metal-film resistors perform well at high pressures; and the type with a carbon film on glass rod seems only slightly pressure-sensitive. But conventional molded fixed-composition resistors show substantial decreases in resistance (20% or more).

The sensitivity of carbon composition resistors may be a credit rather than a debit, however. They show potential for use in pressure transducers, especially where inexpensive, medium-sensitivity units are required.

The component tests are continuing, and a full report is expected when the work is complete.

New light on metal strength and hardness

New data on the structure of metals will be coming from Northwestern University's Material Science Lab as a new series of tests on single crystals and plated deposits gets underway.

Prof J. B. Cohen, who initiated the project, expects it to provide a good deal of information on shock effects and deformation, and on how electrodeposits form.

First single-crystal tests on copper indicate that twinning is affected by crystal orientation. Shock waves applied in one direction seem considerably more effective in producing this structural change than shock waves applied in other directions.

Structural studies of electroplated coatings thus far indicate that organic molecules present in the plating solution may nucleate faults in the metal. Temperature also seems to play a major role. The lower the temperature, the greater the number of faulted regions, and the higher the strain.

Shot-peening retards stress-corrosion cracking

The tendency of steels to fail by stress corrosion in hot, high-purity water can be reduced by shot-peening the surface, a report prepared for NACE indicates. When properly incorporated into a specific product design, says Henry Suss of GE, controlled shot-peening applied to AISI 410 stainless provided protection at stresses to 45,000 psi (about ½ of yield strength) for prolonged periods at temperatures to 300 F; and for shorter periods at stresses to 60,000 psi.

Helium isotope for colder research

Sporting a significantly lower boiling point than its sister atom, helium 4, helium 3 can help provide new information on behavior of materials at low temperatures; and it's now becoming available on a "commercial" basis. Similar to its bigger and better-known relative in most respects, helium 3 is distinguished not only by its lower boiling point, 3.2 K (−454 F) as compared to 4.2 K (−452 F) for natural helium, but also by apparently not undergoing a thermodynamic transition at low temperatures under vacuum.

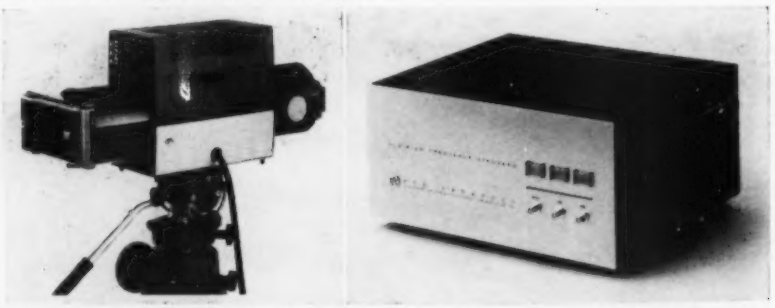
Monsanto Chemical's Mound Laboratory is supplying it, at a base price of 15¢ per milliliter. With packaging and handling costs included, price for a 50-ml ampoule is $25.

briefs . . .

Semiconductor kit—deluxe in price as well as size—is offered for research by Accurate Specialties Co. It contains more than 25,000 preforms, in 24 different alloys (including pure indium, aluminum-boron, and many other new materials), in a variety of ring and platelet sizes. Price: $100.

Magnetic properties of high-purity iron may be affected by hydrogen content, J. F. Nicholson and Rudolf Speiser told the AIME. Soluble hydrogen (introduced by cathodic charging), decreases saturization magnetization; while occluded hydrogen increases the coercive force and decreases remanence. The changes may be of a very high order—increasing the area of the hysteresis loop by as much as 70%—yet without affecting hardness or other physical properties. Furthermore, the effects of hydrogen are not reduced by heating—at least to 860 F. Annealing at 1600 F will, however, cancel out the effect.—**ARG**

Two new ones for the lab



THE "WORLD'S FASTEST CAMERA," and a highly accurate frequency standard, are to be placed on the commercial market by Space Technology Labs early in April. The camera (left) takes pictures at exposure times from 3 to 200 millimicrosec. The frequency standard (right) is an optically pumped rubidium resonance cell, claimed so accurate it will show less than one second of error in 750 years. Prices match the claims. The camera is $20,000; the frequency standard $22,500.

if special application FHP motors are on your mind... write for R&M's new Bulletin 445

This informative bulletin illustrates and describes in detail Robbins & Myers broad new line of Special Application FHP Motors.

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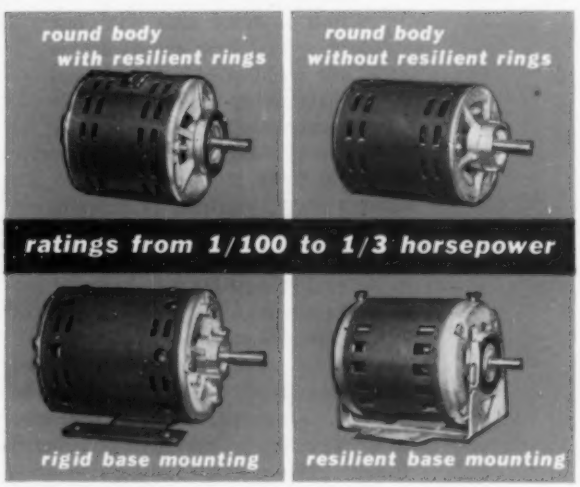
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round body without resilient rings
ratings from 1/100 to 1/3 horsepower
rigid base mounting
resilient base mounting

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DEVELOPMENTS TO WATCH...

Two new lubes ready, another on the way

Dewaxed mineral oils offering "exceptional thermal stability," an improved turbine oil, and a new multipurpose EP grease are announced by Esso Research & Engineering.

The grease is a reformulation of the Esso Nebula line, which not only permits cost reductions in processing but also improves storage stability. Properties are improved, too, says Esso, so the grease will give better service in automotive-type applications and in textile, paper, coal-mining, and steel-fabricating machinery.

The oil, too, is a new formulation, twice as resistant to oxidation as previously available turbine oils, and providing better rust inhibition, higher viscosity index, and greater resistance to foaming.

The mineral oils, still in pilot stage, are now being evaluated by the Air Force for service in supersonic equipment. The other two are ready for commercial use.

Sintered-bronze bearings to offer lower friction coefficients

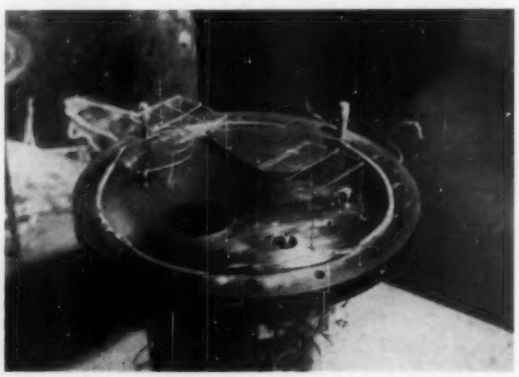
By holding permeability (size of interconnecting passages) to a low value, and thus restricting the rate of oil feed, Bound Brook Bearing Corp, Bound Brook, NJ says it is now able to produce sintered-bronze bearings with unusually low coefficients of friction. In typical bearings meeting all MIL specs, including specific gravity and oil volume, Bound Brook claims, coefficient of friction for a bearing with supplementary lubrication running at 50 psi and 50 to 400 fpm is reduced to 0.02 to 0.04—a decrease of 70 to 80% in friction loss.

Two-cycle engines going out?

Shift to 4-cycle engines for those midget cars called karts is predicted by at least one company in the field, and other 2-cycle equipment may follow suit. The reason: the 4-cycle engines cost less to operate and maintain, and thus offset their higher initial cost. Also, equipment of this type is getting larger and fancier, and needs the increased power and reliability.

Aluminum seals—higher vacuum

A high-vacuum system that features simple aluminum-wire gaskets has been designed in Britain for evaporative deposition of metal films. It's one of several new approaches to the problem of achieving and maintaining lower and lower pressures. (For news of others, see *PE—Nov 7 '60, p 9* and *Jan 9 '61, p 7.*)



ALUMINUM SEAL can be peeled from baseplate if baking temperature is held below 600 F. Strong, permanent joints can be achieved by repeated baking at higher temperatures.

As L. Holland, of Edwards High Vacuum Ltd points out, vacuums on the order of 10^{-5} or 10^{-6} mm Hg are about the best that can be attained with conventional rubber seals. But today's research calls for pressures down to 10^{-10} Hg; and, in most cases, requires baking of the valve. This can be a disadvantage since it often results in seal failure by differential expansion. In the new system, baking helps rather than hinders production of a sound joint.

The gasket is simply a length of aluminum wire, fused to form a ring, which under the pressure and heat (500 F) of baking will stick to the mating stainless steel flanges.

Holland explains the bonding action on the basis of frictional rubbing of the aluminum against the stainless steel as the aluminum creeps during baking.

High-strength wire goes commercial

Tensile strengths in excess of 500,000 psi have been reported for at least 3 types of commercial wire, DMIC reports. A survey by Battelle Memorial Institute shows high-carbon steel is the current champ. In 0.004 in. dia, it has a tensile strength of 600,000 psi. At least two mills are now producing it commercially for filament-wound structures.

Stainless steel wire in fine diameters has a tensile strength of about 300,000 psi; and cold-drawn nickel and nickel alloys are at 200,000 to 300,000 psi.

For tungsten, strengths to 900,000 psi have been reported; but the commercial limit (for 0.001-in. wire) is about 550,000.

All of these are made to commercial standards for uses ranging from rocket-motor cases to reinforcing cloths.

Improved metal coats are on the way

Electroless deposition of cobalt, copper and palladium should be on a commercial basis before the end of this year, and electroless chrome, iron, and vanadium alloy coats will be well on their way to practical application, predicts W. A. Wesley of International Nickel Co, president of the American Electroplater's Society. A good many companies are working on this, and progress has been very rapid.

Coming up, too, are better processes for plating aluminum and for producing combination metal-oxide coats, the latter based on electrophoretic techniques (*PE—Oct 10 '60, p 8*). Details are not yet available on most of these, but there will be more news in the months ahead.

Automatic photo-copier gives dry copies fast

A unit that's claimed to be "the first truly automatic photocopy machine," with greater flexibility and wider photographic latitude than any now available, is soon to be introduced by General Aniline & Film Corp's Ozalid Div. It says the new reproduction system eliminates the need for "sandwiching" the paper and original, produces dry copies directly and immediately. Units are to be priced from about $100 to $600, and will be in national distribution in about a month.

New standards nearing for printed circuit boards

A research program aimed at developing improved tests for peel strength and thermal expansion of copper-clad laminates at elevated temperatures is getting underway at U of Delaware under NEMA sponsorship. It's part of a major study of electrical laminates, under the supervision of Prof M. G. Young: a program that will also test insulation resistance of laminates at elevated temperatures and devise new nondestructive means for determining depth of surface pits, dents, and scratches in copper-clad laminates. It is expected that at least two new test methods will be ready for industry evaluation before end of this year, with others to follow.

Magnet wire improved by annealability control

Control of copper processing to minimize antimony and bismuth content can produce a considerably superior grade of wire-bar copper, Kennecott Copper researchers told the AIME. It is particularly important for wire that is to be coated with organic dielectric enamels (urethanes and the like) that cure at low temperatures.

Because these enamels are baked at low temperature, annealing of the magnet wire may be incomplete, with an undesirable "springy" condition as a result.

The obvious solutions are to use higher baking temperatures, or to pretest and preselect the copper for low-temperature annealability. But neither is a good answer. The best way, of course, is to produce a copper with the desired characteristics. Kennecott's researchers think they now know how it can be done.

Two elements, antimony and bismuth—even in very low concentrations, appear primarily responsible for the undesirable annealing characteristics, with antimony the most serious offender. Control of their content, the Kennecott researchers believe, will permit production of a superior grade of wire-bar copper. Additional test are now being made.

—ARG

R B&W FASTENER BRIEFS

RUSSELL, BURDSALL & WARD BOLT AND NUT COMPANY

Technical-ities

By Fred E. Graves

Fastening of rigid joints

Theoretically, there's no such thing as a rigid joint. There's always some elasticity of the fastened metals. For practical purposes, you can consider a joint rigid when the bearing areas of the metal-to-metal fastened members will not crush or yield before the full load-carrying capacity of screw or bolt is developed.

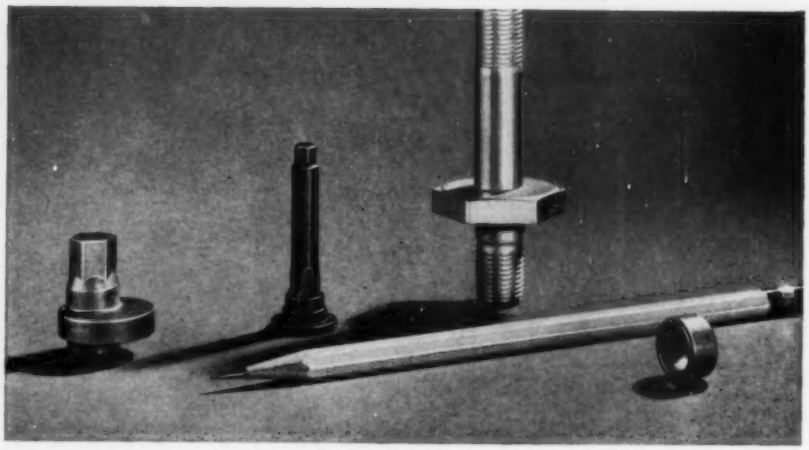
PRODUCT BENEFITS

Rigid joints afford a definite product advantage. They can take high strength hex screws or bolts tightened up to fastener yield strength or beyond. Under such tension, fasteners have demonstrated that they'll stay tight despite vibration. They are resistant to fatigue from the constant load reversals. High Strength Hex Screws cut costs and speed assembly too, since you can reduce *size* of the fasteners or their *number*, while actually improving joint strength.

INSTALLATION HINTS

When you're connecting steel members of fairly heavy section, you've no problem getting a rigid joint. Just clamp them to the full fastener capacity. Thin sections can be reinforced and similarly fastened. And in joining milder steels or softer metals, use of a plate washer will distribute bolt load, prevent crushing and give the desired effect of rigidity.

When to plan on cold-formed special parts



COLD forming is basically a large volume, low cost method of obtaining component parts.

Above you see four specific *types* of parts that benefit from this production method:

ECCENTRIC SHAPES

When the piece is radically eccentric, and is further complicated by having several different diameters, cold forming may prove the only way to produce the piece at a reasonable cost. Machining it from a bar would be prohibitive in scrap loss and machining time.

MULTI-DIMENSIONAL DESIGNS

When pieces are complicated, cold formers can often shape item in two or three blows. Tolerances are close enough for practical uses, and no further finishing need be done except for some secondary machining or drilling if required by the design.

ONE-PIECE PARTS

When simple, small two- or three-piece assemblies can be replaced with unit parts, the production man saves assembly time as well as material costs; the designer gets a stronger part. For example: stud with integral hex, square, or round upset anywhere in-between. Note the extreme upset shown.

PARTS WITH HOLES

Nut formers produce parts by the thousands per hour like the one shown above. Holes are punched out, leaving smooth, clean, work-hardened and strengthened surfaces.

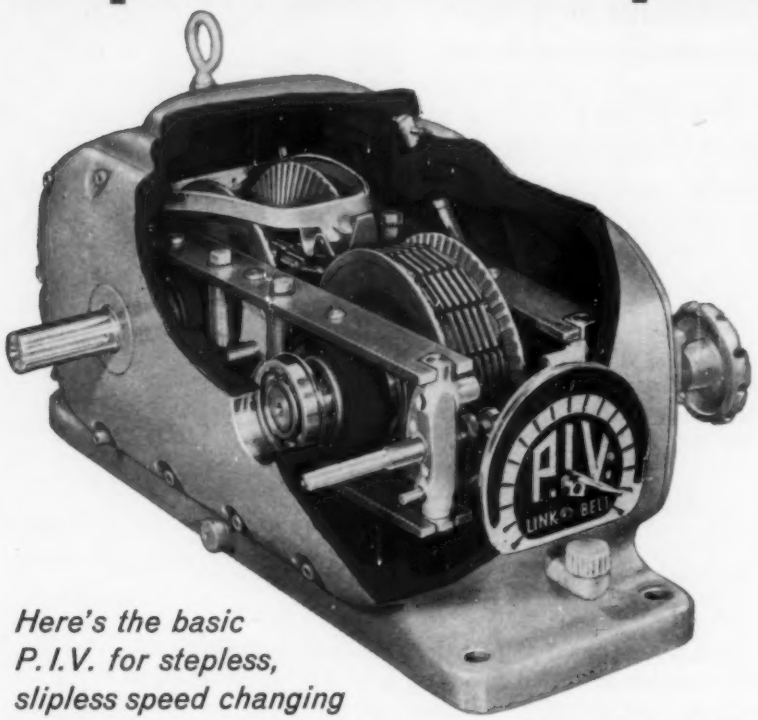
Bear in mind that unlike machining, cold forming cuts none of the metal's flow lines. So parts are tougher and more fatigue-resistant, as well as more economical.

As a fastener manufacturer, RB&W makes an ideal and experienced source of supply for such items. The same facilities used for standard screws and nuts can also pound out the required specials. Refer your problem to Russell, Burdsall & Ward Bolt and Nut Co., Port Chester, N. Y.

Plants at: Port Chester, N. Y.; Coraopolis, Pa.; Rock Falls, Ill.; Los Angeles, Calif. **Sales office and warehouse at:** San Francisco, Calif. **Additional sales offices at:** Ardmore (Phila.), Pa.; Pittsburgh; Detroit; Chicago; Dallas.

LINK-BELT P.I.V. is available in all these ways for

super-sensitive quality control



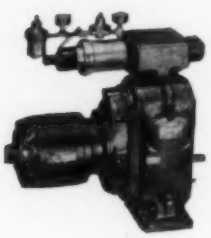
Here's the basic P.I.V. for stepless, slipless speed changing

Today a growing number of production machines and operations demand extremely accurate transmission of power with variable speed control. For these requirements, Link-Belt P.I.V. is available in the many ways shown below—with automatic controls and integral differential to satisfy an infinite number of variable speed applications.

Variable from top speed to minimum speed with no steps, no stops in between, Link-Belt P.I.V. is industry's only chain-driven variable speed drive. Teeth—not tension—permit positive, high-efficiency power transmission.

For information on the full P.I.V. line, call your nearest Link-Belt office. Or write for Book 2274 on basic P.I.V., and Book 2774 explaining P.I.V. with integral differential.

Link-Belt P.I.V. is available in 8 sizes and 16 standard types, in capacities from ½ to 25 hp—for horizontal or vertical mounting. Compact design simplifies installation as a separate unit or a built-in part of a machine. P.I.V. is totally enclosed, automatically lubricated.



PNEUMATIC (shown) — The P.I.V. pneumatic ratio changer is used as a final control element providing fully automatic control of speed. Operates from standard pneumatic controller in systems regulating pressure, temperature, rate of flow, etc.

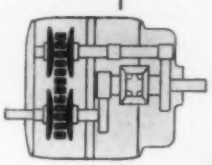
MECHANICAL — Predetermined timing, cyclic, or characterized regulation can be accomplished by P.I.V. with mechanical controls.

HYDRAULIC (shown) — Consists of a low-pressure hydraulic Servo system with a precision valve positioner. Intended to give automatic speed control by direct operation with any form of linkage. A minimum operating force is required.

ELECTRONIC — Flexible form of speed control to provide either "on-off" or modulated speed response of P.I.V. drive. Electric control motors are available to match a wide variety of electrical control systems.

P.I.V. with integral differential gearing

CONDENSED SPEED RANGE TYPE of integral differential results in a ratio range less than a standard P.I.V. with the advantage of increased horsepower capacity, high ratio stability and accuracy. These drives are applicable wherever small ratio range is required but with extreme accuracy of ratio control.



EXTENDED SPEED RANGE TYPE of integral differential results in infinite ratio range and output speeds down to zero with a constant input speed. Clockwise and counterclockwise rotation through zero is also obtainable. These drives may be used whenever a ratio range greater than 6 to 1 is required.

LINK-BELT P.I.V. VARIABLE SPEED DRIVES

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices and Stock Carrying Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs. Representatives Throughout the World. 15,183

FROM WASHINGTON . . .

Boost in weapon budget expected to take $2 billion

Defense spending is expected to be increased by about $2 billion by Pres Kennedy. This comes on top of the $42 billion military budget previously sent to Congress by Pres Eisenhower. The increase is result of an extensive reappraisal of the military budget ordered by Pres Kennedy when he took office on January 20.

The emphasis will be on items geared for limited war capability. Increased spending will focus on such things as basic army weapons, transport aircraft, and possibly tactical fighter planes and naval transports.

Strategic weapons will also get a boost by pumping more money into the Navy's Polaris Missile System and the Air Force's Solid Fuel Minuteman ICBM.

Accelerated defense spending already adds up to $1.4 billion. It includes $597 million for five additional Polaris submarines, $125 million on transport planes, and $650 million worth of new contracts to be let soon under the Administration's anti-recession drive.

Small business can expect more military contracts

Small companies are to get special attention in new defense spending. Secy of Defense McNamara has ordered the military to channel more contracts to small business.

The armed services have been directed to limit the use of noncompetitive, sole-source contracting whenever possible. And they have been told to "find greater opportunities" for small-business set-asides in defense contracts.

As an example of the move to get secondary sources of supply on production items, Navy recently called in over 200 small firms to bid on furnishing components for its Bullpup missile.

Currently, the Martin Company has the production contract for the missile. But Navy indicates that unless costs are chopped sharply it may seek production elsewhere.

Materials study gives nod to ceramics

Ceramic research will be pushed by the Department of Defense. That is what a special report on materials research recommends. Ceramics are considered to offer the best high-temperature possibilities of any material under development, and are expected to fill in the research area beyond refractory metals.

Design limitations arising from ceramic brittleness is expected to be overcome. The report is the result of special panel studies on materials made by the Office of Defense Research and Engineering, the Materials Advisory Board of the National Academy of Sciences, and materials studies by other defense agencies.

123 new inventions wanted

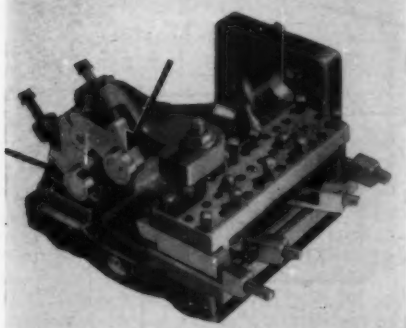
The Armed Forces wants inventors to come up with 123 new inventions. A full description of the needs has just been published by the National Inventors Council. It includes such items as a quiet 25-hp hydraulic pump; a multipurpose pump weighing less than one pound but capable of pumping 30 to 40 gpm; a quiet high-torque speed reducer able to handle 50 to 1000 hp. A complete list of the inventions wanted can be obtained from the National Inventors Council, OTS, US Department of Commerce, Washington 25, DC.

McGILL® CAMROL® BEARINGS

are proven performers—with cost and assembly advantages

McGILL CAMROL bearings have rolled up an unequalled 25-year history of high performance and dependability — with the cost savings of standard bearings over built up shaft and roller units. They eliminate the time-consuming intricacies of procurement and assembly of parts for improvised bolt, bearing and washer followers. You, too, can rely on the designed-in ability of CAMROL bearings to accept intermittent shock and fluctuating heavy loading coincident to cam action, track or guide and support applications. CAMROL bearings are built for stock in roller diameters from ½" to 4" in the CF series with integral stud and the CYR series for shaft mounting. Both types are available with or without positive, integral seals for retention of prelubrication and protection against contaminants. Following are typical applications.

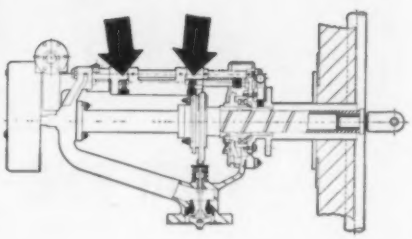
GISHOLT MACHINE COMPANY incorporates McGILL CAMROL® bearing accuracy into tooling set-ups

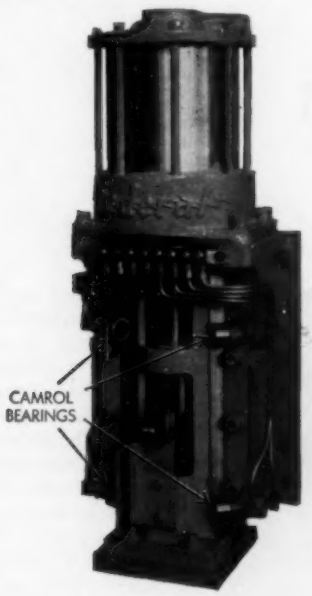


Gisholt Machine Company takes advantage of the cost and performance features of CAMROL CF series bearings, (with integral stud), on a group of standard bar tools for mounting on the turrets of Gisholt Masterline Turret Lathes. A representative tool of this group is the Multiple Cutter Turner shown.

CF CAMROL® bearings provide rolling contact in automatic soot blowers

Diamond Power Specialty Corporation has incorporated McGILL CAMROL bearings into the design of their Model IR Short Retraction blowers to produce a smooth rolling contact between cam flange and latch bar. This equipment is used for cleaning water cooled furnace walls, hopper slopes or narrow portions of tube banks adjacent to walls automatically.





FEDERAL MACHINE and WELDER COMPANY puts McGILL uniform quality into welding equipment

The anti-friction welder head unit, shown, is one of the several applications of McGILL CF CAMROL bearings in Federal Machine and Welder Co. equipment. CAMROL bearings are used in weld heads, transfer slides and various other uses where a precision, smooth, uniform movement is desired. Low cost, uniform quality, excellent performance and exceptional length of life are benefits gained in eleven years of use of CAMROL bearings.

Both the regular CF Series and the prelubricated and sealed SCF Series CAMROL bearings are used in Federal equipment.

engineered electrical products

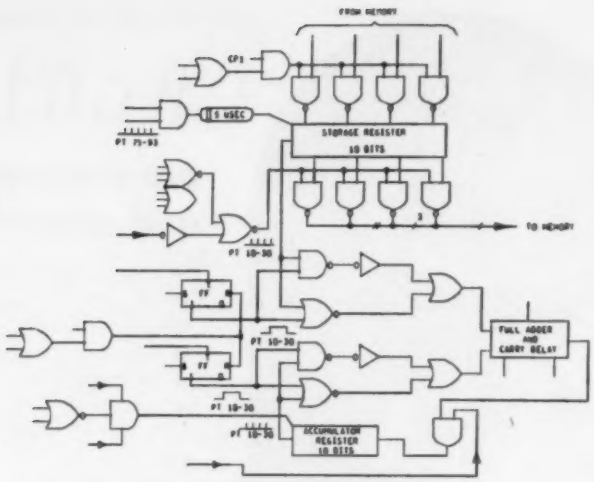
McGILL®

precision needle roller bearings

Send for free copy of McGILL Bearing Catalog No. 52-A.

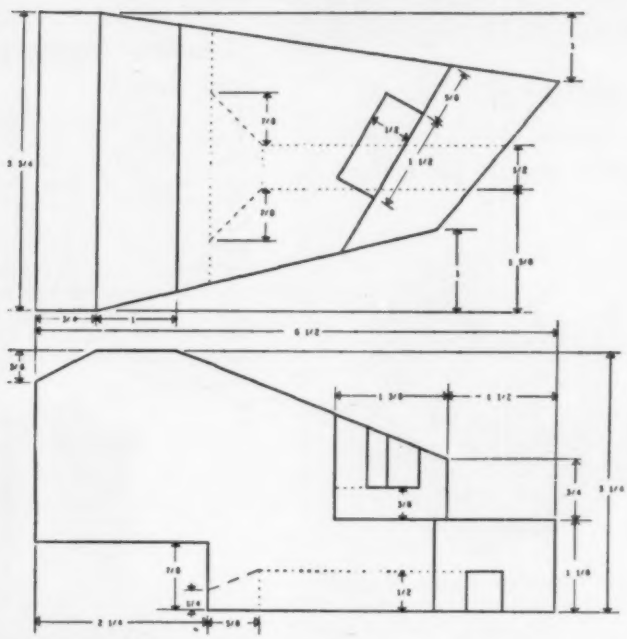
MULTIROL-GUIDEROL-CAMROL-CAGEROL

McGILL MANUFACTURING CO., INC., Bearing Division
201 N. Lafayette Street, Valparaiso, Indiana



Actual drawings produced by the S-C 4020 High-Speed Microfilm Recorder

NOW! Automatic drafting like this from your computer in less than 1 second!

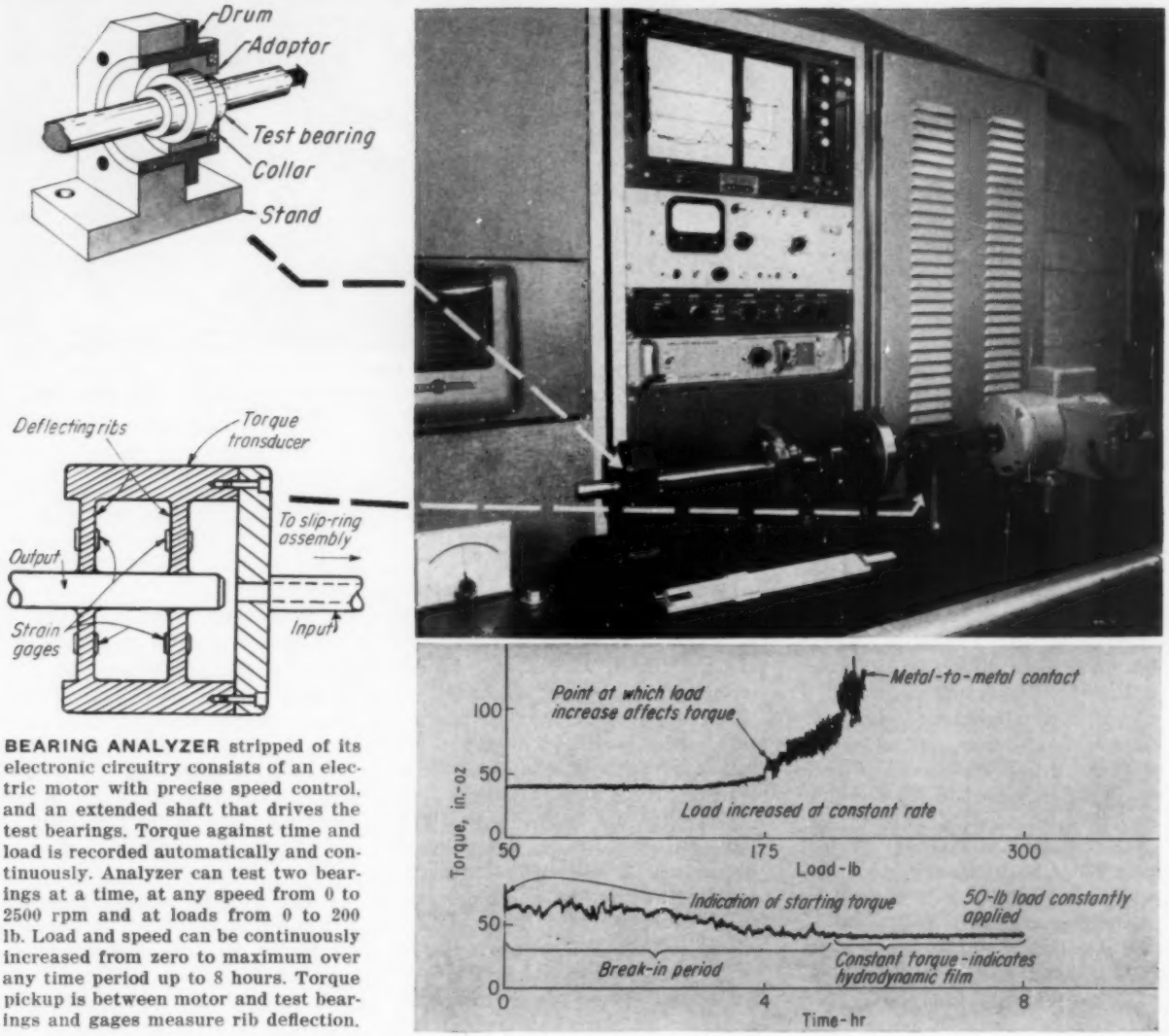


The S-C 4020

Instantaneous mechanical drawing is now a reality, with the Stromberg-Carlson S-C 4020 High-Speed Microfilm Recorder. Automatic drafting can cut weeks from design time, saving invaluable engineering man-hours. Here's how it works:

A computer is programmed with the contours and specifications of the part to be designed, using APT (Automatically Programmed Tool) language. The computer operates the S-C 4020 Recorder which makes multi-view mechanical drawings of the part in a fraction of a second. After the drawings have been checked, output of the computer can be used to operate a numerical control tool and produce the part. Capabilities of the S-C 4020 include recording data on microfilm at 17,500 points per second, plotting graphs on microfilm at 12,500 points per second, recording complex logic circuit drawings, tabular printing and forms projection. Write for more details to Stromberg-Carlson-San Diego, Dept. B-22, P. O. Box 2449, San Diego 12, California.

STROMBERG-CARLSON-SAN DIEGO
A DIVISION OF **GENERAL DYNAMICS CORPORATION**



BEARING ANALYZER stripped of its electronic circuitry consists of an electric motor with precise speed control, and an extended shaft that drives the test bearings. Torque against time and load is recorded automatically and continuously. Analyzer can test two bearings at a time, at any speed from 0 to 2500 rpm and at loads from 0 to 200 lb. Load and speed can be continuously increased from zero to maximum over any time period up to 8 hours. Torque pickup is between motor and test bearings and gages measure rib deflection.

Analyzer Discounts Machine Torque, Gives Accurate Bearing Record

DETROIT—Completed section of the bearing analyzer being developed by the Tann Corp (*PE*—Feb 27, p 9) is already measuring and recording the effects of variations in load and running speed on bearings. When completed next year, the analyzer will also measure shaft deflection, thickness of hydrodynamic oil film, noise and vibration, and other effects.

By varying the load and speed, say Tann engineers, they can determine with extreme accuracy the optimum operating conditions for any bearing configuration. This checks such design changes as material selection and surface finish, lubrication, and variations in length-to-diameter ratio.

The Tann analyzer is said to be the first system that can measure only the torque in the test bearings while electronically eliminating the torque and vibration from the mechanism of the test equipment. Heart of the machine is a device which isolates the torque used by the bearing under test.

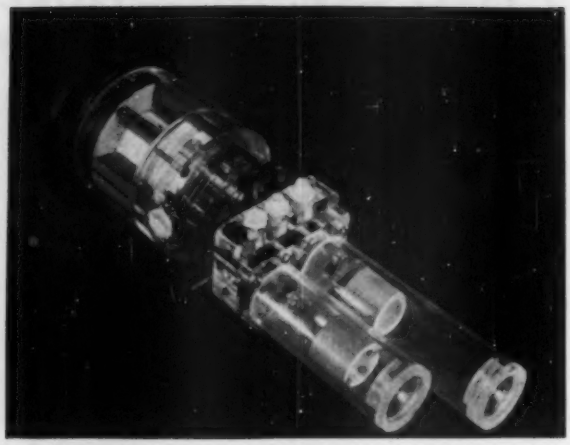
Basically, Tann reports, this device is a spider transmitting torque from the source to a shaft through radial ribs. Strain gages on the ribs measure rib deflection, a function of the transmitted force. Output of the gages is collected through slip rings in a torque pickup transmitter, then amplified to drive a recorded mechanism.

Test bearings are placed in a simulated motor-housing mount which can duplicate bearing placements of integral-hp motors with NEMA 184 to 254 frames.

The new analyzer has already been used to determine break-in time for a new bearing under steady load, effect of increasing load on the bearing's operation, and point at which the load ruptures the hydrodynamic oil film and metal-to-metal contact starts.

—Felix Giordano, Regional Editor

THE EARTHMOVER, under test by army engineers, is shown here scraping earth ballast into its bowl. Apron and dozer blade are partly raised to permit intake of earth.



SUSPENSION UNIT for tractor wheels includes rotary actuator and accumulators shown here. Unloading the accumulators cuts out the springs.

Ten-ton Tractor Tests Hydraulic Suspension System

Ft Belvoir, Va—A radically new design for an earthmoving tractor is being tested by the US Army Engineer Research and Development Labs here. Developed by International Harvester Co, the 21,000-lb crawler-tractor is about 40% aluminum, has a front-loading arrangement and a unique hydropneumatic suspension system.

These design characteristics grew out of requirements laid down by army engineers, who wanted a tractor that could be used in combat. Such a vehicle had to be light (its 21,000 lb would allow airlifting it to advance positions) and perform multiple functions rapidly, yet still be simple to operate and maintain. The test vehicle, called the Universal Engineer Tractor, can travel over roads on sprung tracks at 30 mph. The same tractor operates in a solid "unsprung" state for off-road work as a dozer scraper, grader, or dump truck. It can also carry cargo or personnel over land or water.

SUSPENSION KEY TO VERSATILITY

Versatility of the system derives largely from the hydropneumatic suspension system. Each of the tractor's eight wheels is individually sprung by hydraulic rotary actuators coupled to gas springs (accumulators). When the vehicle is required to do heavy earth-moving jobs, the springs are blocked out of the system and the vehicle noses down into the earth. The springs can be switched back into the system for light operations or overroad driving. A control handle on the instrument panel controls this changeover.

Both height and tilt of the dozer and scraper cutting edges are governed by hydraulic fluid in the actuators. To tilt-scrape or tilt-doze, the tractor operator actuates wheel-control valves separately or in varying amounts.

Another novel feature is the machine's front loading. By loading with ballast of earth or whatever else is available in the area, the vehicle can obtain maximum drawbar pull of 17½ tons—equivalent to a conventional tractor twice as heavy (empty weight).

Keeping within the army's airborne-width limitation of 110 in., IH designed an interior-bowl configuration in the ballast compartment that permits a full 110-in. scraper cut. This was done by putting ramps over the crawler track, which also makes it possible to use the full width above the tracks for ballast or cargo space. Capacity of the bowl is from 7.4 to 8.5 cu yd, depending on how it is packed.

International Harvester began developing the new tractor in May 1958 under a $760,000 contract which included construction of a prototype. Tests of the vehicle were started in June 1960 at Libertyville, Ill, before it was brought to Ft Belvoir last November. Since then it has undergone continuous testing by army engineers.

Results, they say, have been more than satisfactory, but there are some changes they now want. A second contract for $720,000 has been given IH to build two followup versions. The next model is due here in November. It will weigh 1000 lb less and is expected to have the following three basic changes:

- A hydrostatic transmission—one of the largest ever built will replace the present power-shift transmission, converter and geared steer unit. The hydrostatic transmission, army engineers say, will increase maneuverability. Its hydraulic pump driving a hydraulic motor will allow infinitely variable speed from zero to 30 mph. And it will allow greater flexibility in turning radius.
- The hydropneumatic suspension system will be simplified. In the present tractor, for example, there are 14 accumulators. These will be replaced by 7. And parts for the left- and right-hand sides of the newer model will be interchangeable.
- A lightweight diesel engine will replace the 250-hp V-8, liquid-cooled gasoline engine in the present test model.

Army engineers expect the new tractors to cut the cost of providing military tractor-support equipment. A fleet of 17 IH vehicles, they think, could replace the 34 pieces of equipment now used by a typical airborne engineer battalion. And if the model is standardized, spare-part requirements would be greatly reduced. In addition, fuel consumption may be reduced by some 52%; the vehicle requires less maintenance, and can be operated by drivers who are less skilled. ■

Typical properties of Celcon (at 73 F and 50% RH)	
Tensile yield str., psi	8800
Elongation at yield, %	12
Tensile modulus, psi	375,000
Flexural strength, psi	12,000
Izod impact (notched), ft-lb/in.	1.1
Deformation under load, % (at 2,000 psi and 122 F)	1.0
Immersion in 10% NaOH, appearance	discolored
Water absorption, 24 hr immersion, %	0.25

New 'Easy-molding' Structural Plastic

NEW YORK—Resistance to creep deformation at high temperatures, resistance to difficult chemical environments like hot alkalis, and outstanding moldability are the three major features reported by the Celanese Corporation of America for its new structural thermoplastic, Celcon. The new resin is described by Celanese as "a highly crystalline linear acetal copolymer based on trioxane." Short-time test data on Celcon (see table above) shows its tensile and flexural properties to be about 10% below those of straight acetal thermoplastics. This combination of characteristics, plus good dimensional stability, is expected to make the new plastic a lively competitor in the auto and appliance markets where high strength and heat resistance are critical requirements. Total consumption in these two fields for Celcon is expected to reach about 37 million lb by 1965, according to Celanese spokesmen. Material for injection molding, extrusion, blow molding and other established thermoplastic fabrication techniques is currently available, in experimental quantities only, at 70 cents/lb. **—Ford R. Park**

Selecting the Right Solder Requires the Right Test Equipment

Two major advantages are claimed by IBM's Product Development Lab, Poughkeepsie, NY, for its new solder-spread analyzer. According to H. H. Manko, developer of the device, these are: (1) instead of comparing wetting conditions on specimens after prolonged heating, it compares stages of wetting as a function of time; this gives a clearer understanding of the solder system under test. (2) The solder and flux can be applied to the base metal at any desired combination of time and temperature—thus simulating a variety of production cycles. This is achieved by using a fast-heating and rapid-cooling element. Base-metal specimens are die-cut disks, with or without plating. Solder is applied in the form of pellets, with closely controlled, constant volume. Photo shows completed specimen on the 5-mil tungsten heating-strip of the analyzer. (Directly beneath is a spring-loaded thermocouple, above is a glass exhaust funnel for flux fumes.) A "solder-spread factor" is computed by measuring height of the spread droplet as a percentage of diameter of a hypothetical sphere having same mass as the original solder pellet. Solder system is then rated on an arbitrary scale from Poor to Excellent, depending on the application and on experience. A similar rating could be devised by comparing spread area or contact angle; however, height measurement is simplest by dial gage. This test helps select the right solder for the job. For more detail on this problem, see p 39 of this issue of PRODUCT ENGINEERING.

Japanese Chemical Formula Promises Better Vacuum Casting

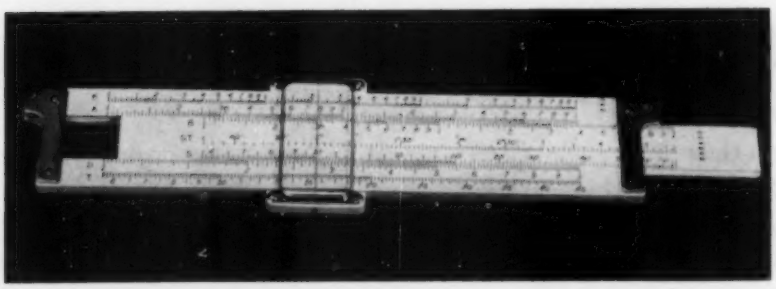
TOKYO—A Japanese inventor has announced development of a new chemical, which, he says, will eliminate impurities in metals during melting. The purer melt reportedly results in a much higher number of perfect castings. Also, it permits vacuum casting of various types of metals without change in foundry equipment.

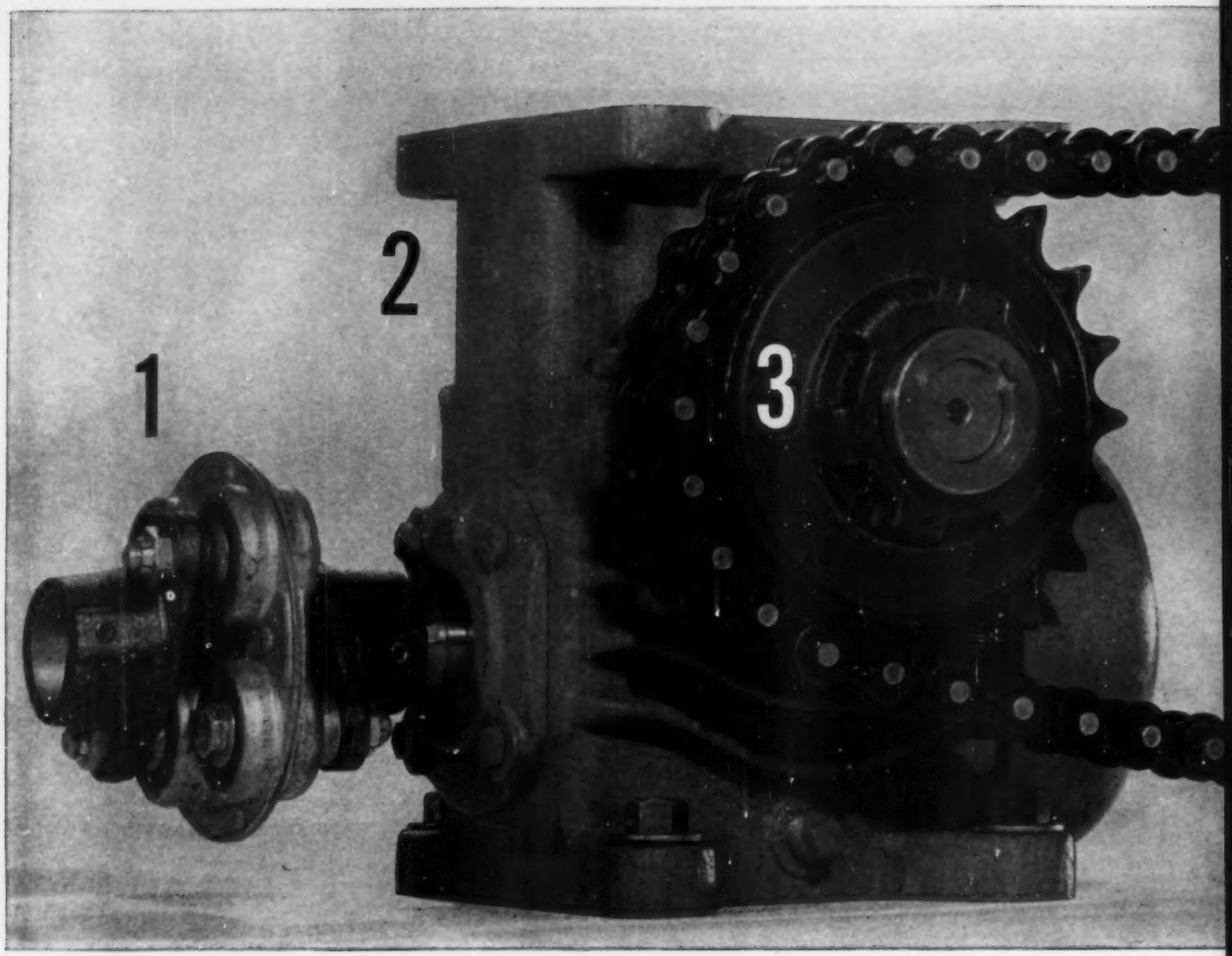
Known as Nujolite, the chemical was first made public at a new-products show here. The show is under auspices of the Tokyo Metropolitan Inventors Association.

According to inventor Teruo Shiraischi, the chemical generates a heavy-gravity chloride gas as the metal heats, thus creating a nonoxidized condition in the furnace. Under such conditions, he says, burning or refining of the various impurities in the metal is hastened. Additionally, the chemical forms a tight seal around the metal when it is poured, thereby preventing oxidation.

The main component of Nujolite is boron oxide. To this is added varying amounts of ordinary salt and reactive metal compounds. The blend varies

continued on page 20





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Flexible Chain	Worm Gear	Cam	Silent Chain
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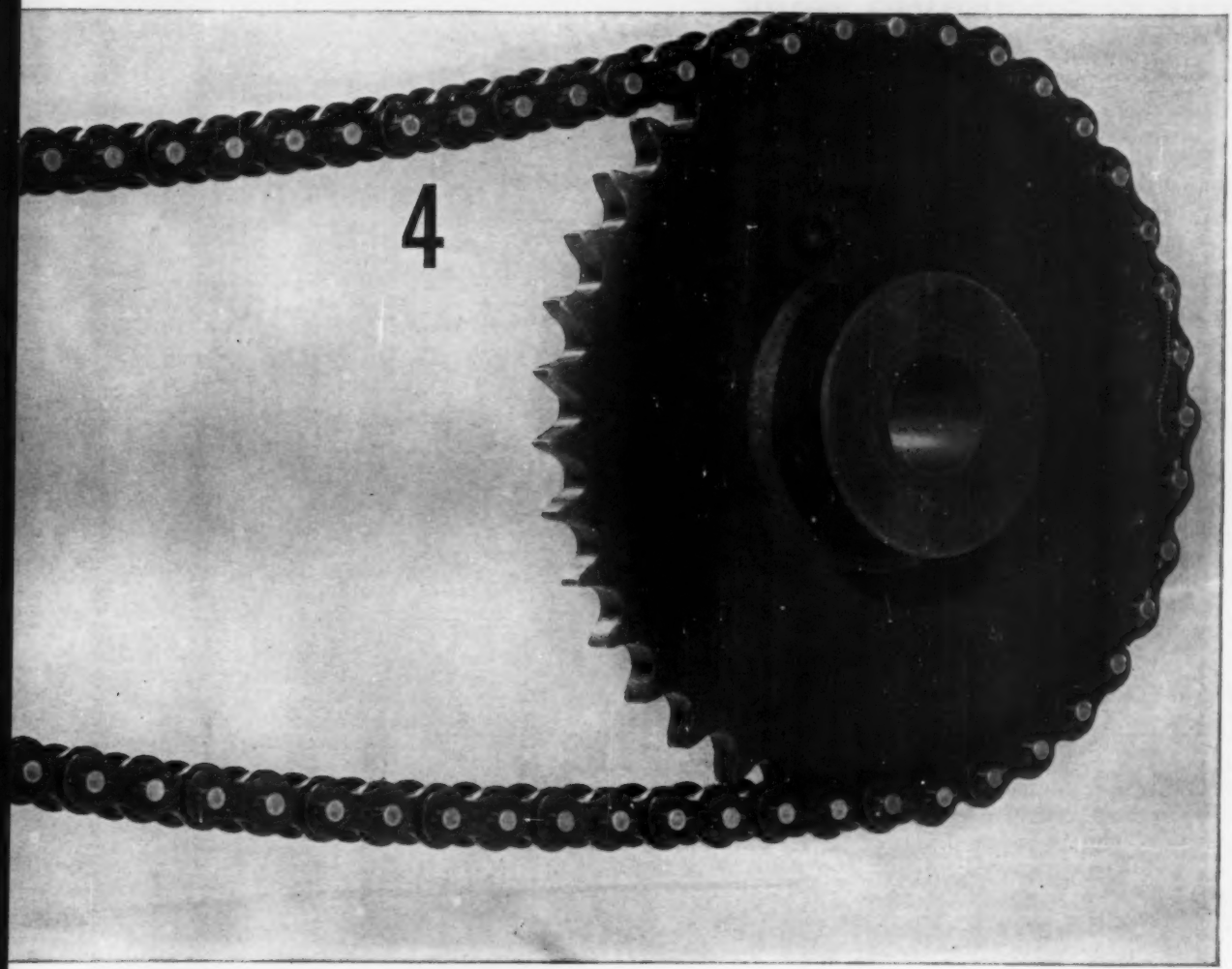
Nylon	Gearmotors	Pullmore	"Timing"® Belt



power transmission needs because only Morse offers transmission components

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continued from page 17

slightly, depending upon metal and its melting point. The new chemical is being sold here for $1.66 a kilogram (about 75¢ lb).

—John Yamaguchi, Tokyo Bureau

Commerce Dept Wants Its Own Technical Chief

WASHINGTON—Congress will be asked to create a post of Assistant Secretary of Commerce for Science and Technology. Secy of Commerce Luther H. Hodges is pushing the measure and has Administration backing. Such an assistant, Hodges says, would provide top-level supervision for the department of the Bureau of Standards, the Weather Bureau, Patent Office and Coast and Geodetic Survey. ■

Japanese Universities Get Financial Aid

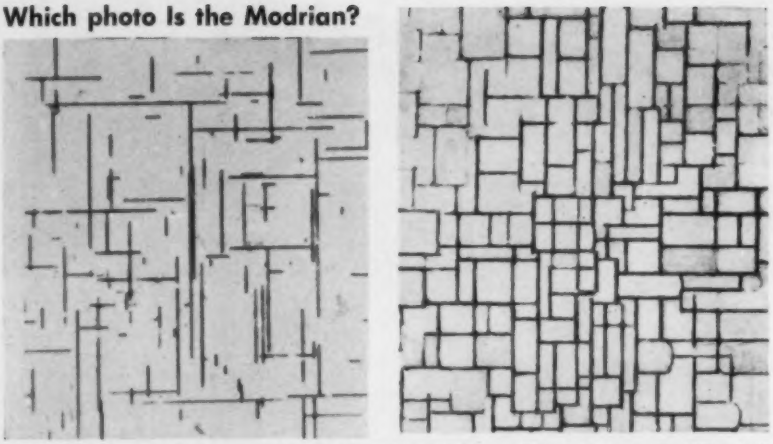
TOKYO—The Japanese Iron and Steel Federation has announced an extensive plan to aid universities here. Purpose is to ensure an increased supply of highly trained engineers for this metals industry. A shortage of engineers is becoming increasingly serious in Japan.

Under the 5-year program, 1 million yen ($2.8 million) will be distributed to five government-run universities. During the first three years, disbursements will be made at the rate of 250 million yen ($700,000) annually. The program will get underway April 1, and will include Hokkaido, Tohoku, Kyushu, and Yokahama National Universities. ■

American Heritage Says PE Is a Good Citizen

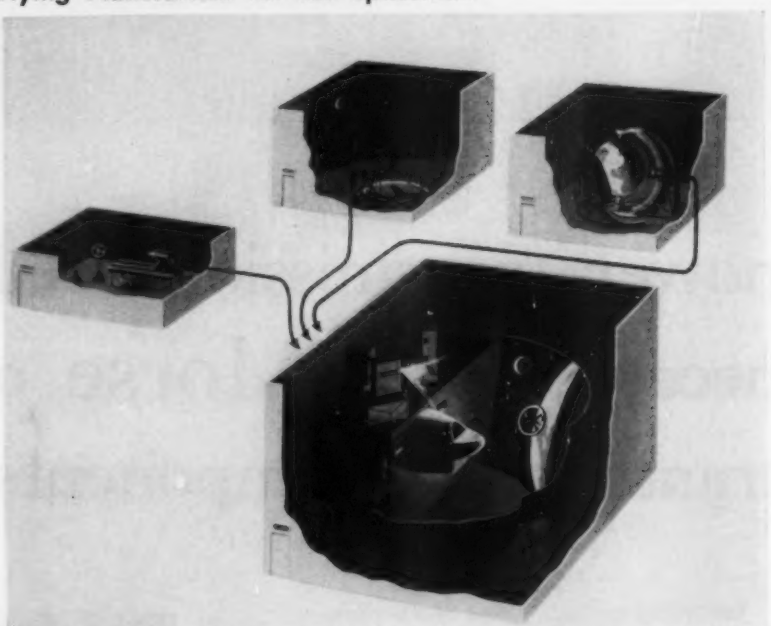
NEW YORK—PRODUCT ENGINEERING was one of nine national magazines to win a citation from the American Heritage Foundation. According to Foundation Pres John C Cornelius, PE was cited because of two editorials and a "Points of View" section urging citizens to vote during the 1960 presidential elections. The award is made to state and local agencies as well as business, industry and communications media under the Foundation's Informed Vote and Contribute-to-your-party Program. ■

Which photo Is the Modrian?



Abstract art may be more realistic than its critics realize—so says Dr Wendell S. Williams of the National Carbon Co Research Lab. In a recent experiment, he heated titanium carbide crystals to 2600 F in a vacuum and split them with a diamond saw and chisel. The split crystals were then etched by immersion in an acid and then subjected to an electric current. Since titanium carbide can accommodate only one carbon atom for each titanium atom, surplus carbon precipitated, forming a geometric pattern (photo, left). Struck by the similarity between this precitate pattern and the geometric style developed by the painter Modrian (photo, right), Dr Williams obtained permission from the present owner of the painting (the Rijksmuseum Kroller-Muller in the Netherlands) to identify his etched crystals as Modrian Precipitation Patterns. The experiments aim to increase basic understanding of mechanical and other properties of high-temperature materials.

Flying Planetarium for the Spaceman



Visual simulator for space-flight trainees being developed by Bell Aerosystems for the US Air Force is visualized by an artist as a theater housing a space-vehicle mockup. The directional screens that show images to the trainee receive them from separate projectors which are in the view field of each space-vehicle window. The three image generation studios (above the theater) supply high-resolution TV pictures to the projectors. The visual simulation here is a composite of images produced by TV cameras viewing an earth globe (upper right), a celestial array (upper center) and a space station model (upper left). All three cameras and models are driven synchronously to move in proper response to vehicle control actions by the flight trainee.

OIL SEALS in Design Engineering

Garlock KLOZURE* Oil Seals stop oil leakage at bearings, increase efficiency of Denison Variable-Volume Hydraulic Pumps.

Denison designs hydraulic pumps around Garlock KLOZURE Oil Seals to assure maximum sealing efficiency.

Where pressures are too high for ordinary lip seals, KLOZURE Oil Seals prevent leakage of hydraulic oil and protect vital bearings as temperatures reach 150°F, pressures rise to 35 p.s.i., and shafts whirl at 1800 r.p.m. In use for the last twelve years, the seals have given complete satisfaction on the well-known line of axial piston and vane-type pumps made by Denison Engineering Division of American Brake Shoe Company.

Wherever bearings must have the best protection, Garlock KLOZURE Oil Seals are specified. On pumps like Denison . . . in steel mills . . . on power shovels and lift trucks . . . for motors, KLOZURE Oil Seals prevent leakage of lubrication, seal out harmful foreign matter. Whatever the application, there is KLOZURE Oil Seal to do the job. They are oil and grease resistant, impervious to mild acids and alkalies, non-abrasive, and will withstand temperatures from −40°F to +250°F. For extreme conditions, Garlock furnishes sealing elements resistant to practically any fluid, and serviceable as high as +500°F.

Availability is another prime reason for selecting Garlock KLOZURE Oil Seals. Once your design is finalized, you may select the proper seal from over 1800 stock models available from 180 national bearing distributors, including one near you.

It makes good sense to design with KLOZURE Oil Seals, as Denison and hundreds of other leading companies have found. See how you can benefit—call in your local Garlock representative. You will find him at the nearest of the 26 Garlock sales offices and warehouses throughout the U.S. and Canada. Or, write for Catalog AD-181. Garlock Inc., Palmyra, N. Y.

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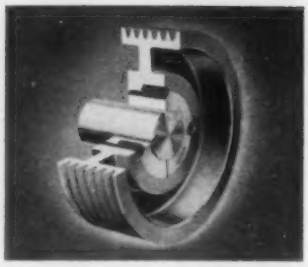
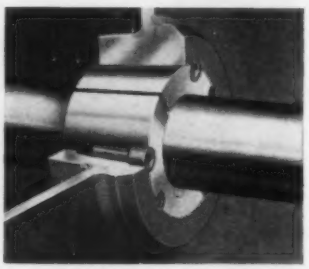


No flange, no collar, no protruding part! Modern, safe, *flush* design. Minimum space on shaft. Mounts as a unit — tighten while sighting. Easy on — easy off!



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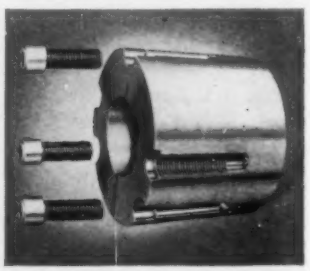

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Proven performance: now in volume production...embody field proven features...track, modules and end clamps molded of tough plastic ...improve dielectric characteristics...proven high-speed HYTIP contact installation tooling cuts installed costs and insures maximum reliability.

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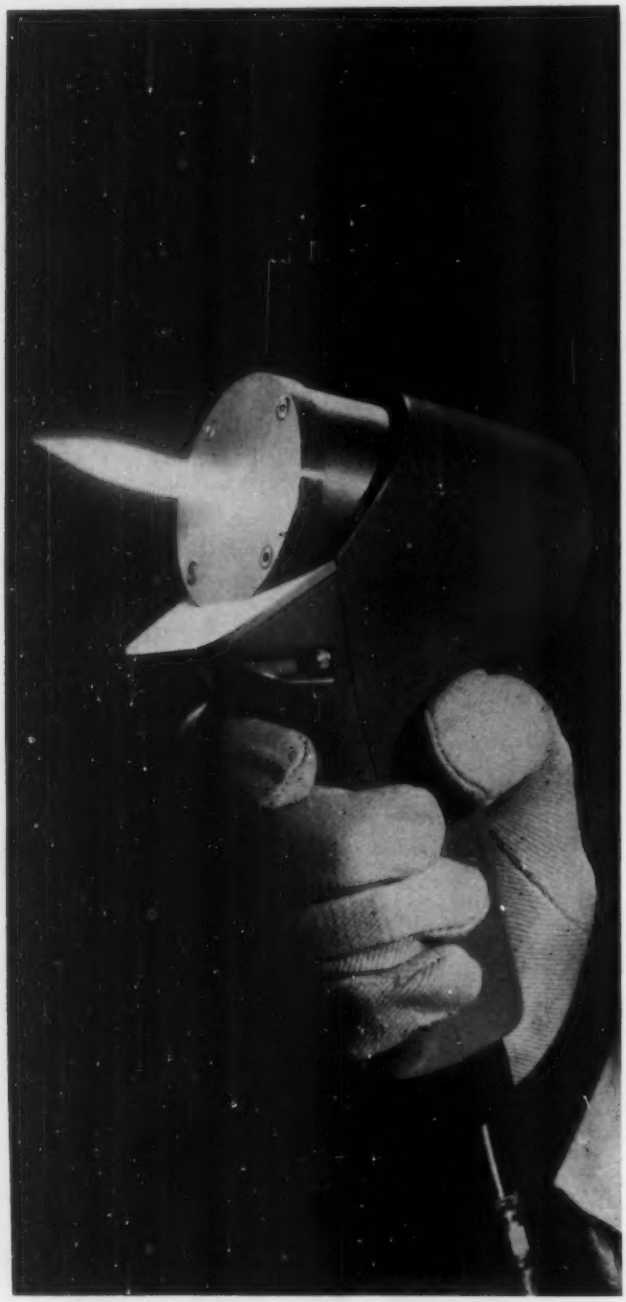
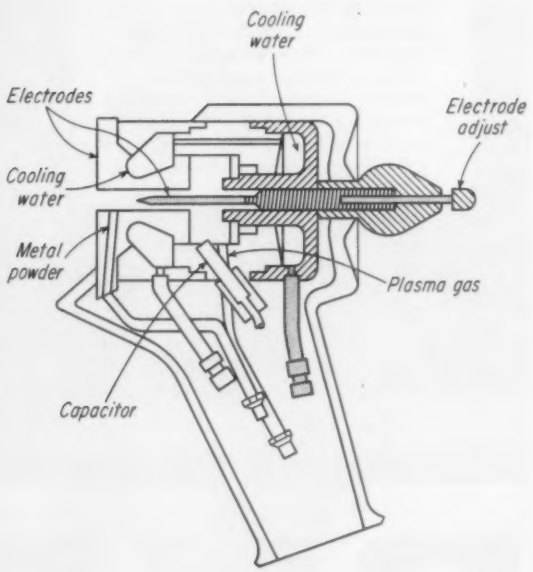
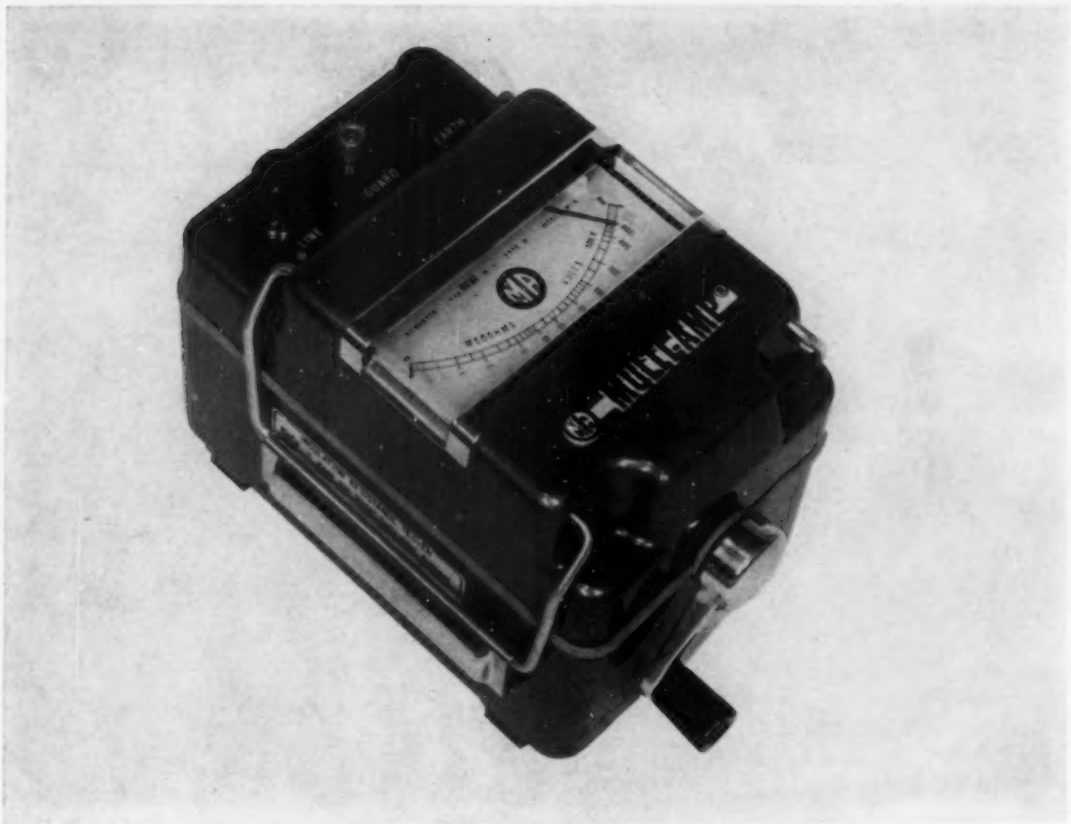
TRENDS IN INDUSTRIAL DESIGN



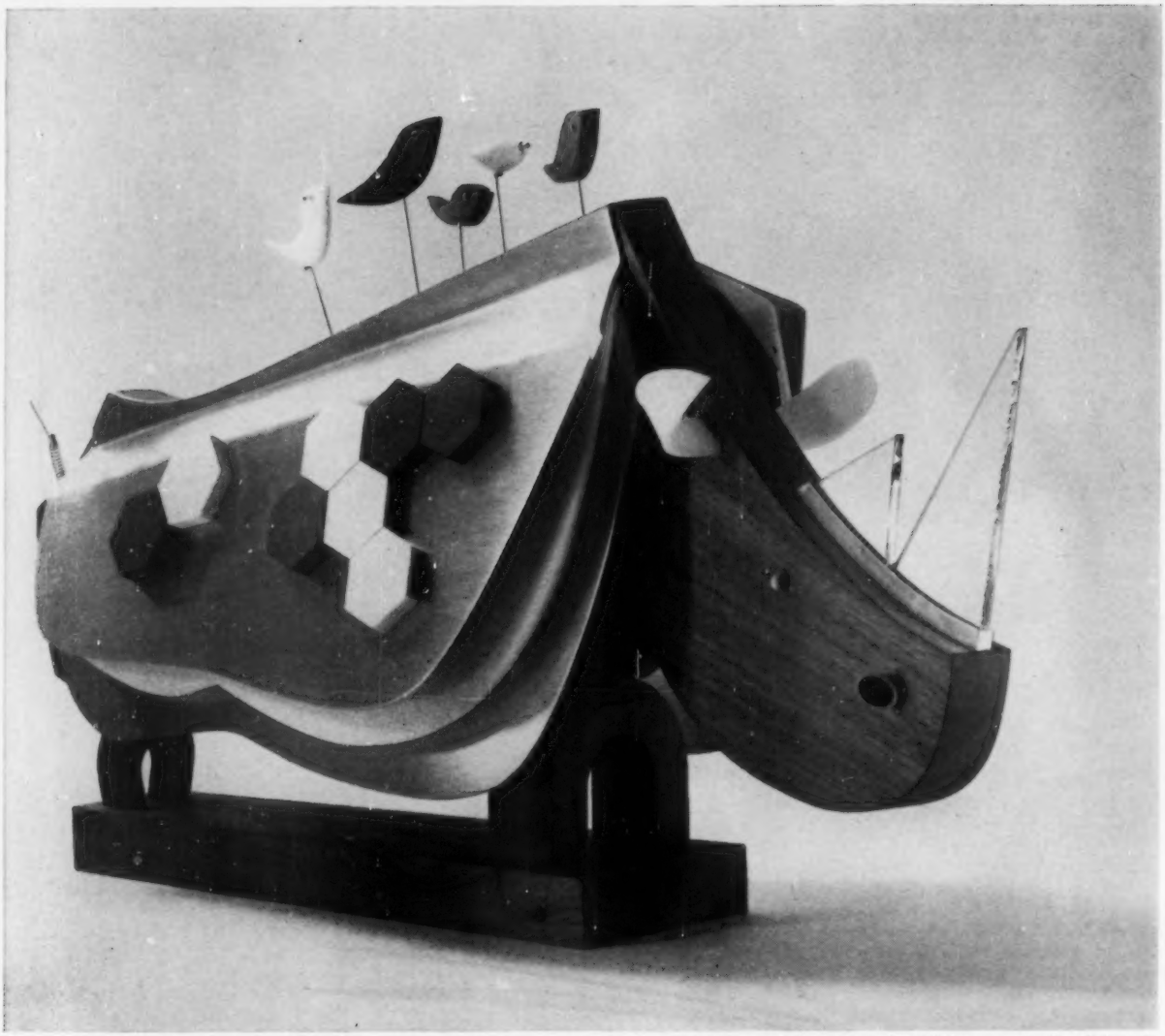
PLASMA HEAT-GENERATORS that are held by hand pose several unusual tool-design problems. Temperatures produced are higher than those produced by any other portable system (as high as 30,000 F). Three cumbersome hoses (for gas, cooling water and the metal powder to be sprayed) and an electrical conductor must be brought through handle to gun's head, which is necessarily a heavy one. Yet the new housing and heat-shield assembly designed by Dean Myers, industrial designer of Newport Beach, Calif, for Plasmadyne Corp, has the minimum bulk and economy of line and detail that characterize all superior tool design. Housing is fiberglass-reinforced plastic, which is formed on tooling of similar composition. Capable of withstanding 400 F for 5 min., as a safety factor, the housing protects operator's hand from the jet's heat with a lip-shape protuberance, topped by a heat-reflective metal plate. The handle was changed from its former hard-to-grasp square shape by realigning the supply lines so that outer shape and dimensions provided better grip contours. Handle was also tilted back at an angle calculated to ensure minimum fatigue. The light, shell-like structure helps hold weight down as much as possible.





PORTABLE TESTER checks insulation resistance of electrical machinery, control systems, communications equipment by applying dc that is internally converted from ac supplied by crank-operated generator. Available for four rated voltages and five ranges of resistance (from 100v/20 megohm to 1000v/2000 megohm), tester is of Japanese design and manufactured for Multi-Amp Electronic Corp, Union, NJ. Upper half of two-piece housing constitutes cover which lifts off to permit maximum accessibility to interior. Recessed connector ledge and corners notched for fold-away handle achieve compactness and eliminate unnecessary protuberances. Full-width, flush meter face is easy to monitor even while cranking.

TWO-WAY CITIZEN'S-BAND RADIO that can be operated with one hand consists of transistor-equipped superheterodyne receiver and 3-stage transmitter with 9-battery powerpack in a 2-piece housing vacuum-formed of ABS poiymer. Cover lifts off for servicing, using grommet that pulls out so that hole in case is large enough to free the telescoped antenna. Weighs less than 4 lb; its range varies from 1 to 10 miles, depending on broadcasting conditions. Designed by Bruce Kamp Assoc, industrial designers of Philadelphia, for Roy Jefferson Inc.



Sculpture created especially for 3M Company by Guy Palazzola

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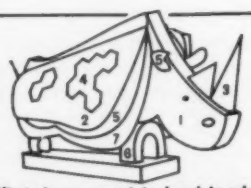
Whatever materials you're bonding (to the same or to another material), a SCOTCH-WELD Brand Structural Adhesive bond will give you a bonus of structural strength at the joint, with the flexibility to resist vibrational fatigue. SCOTCH-WELD adhesive bonds distribute stress loads uniformly, and protect the strength and integrity of the materials by eliminating fastening holes, maintaining the finish, and sealing joints against corrosion.

Fatigue tests show that metal-to-metal joints in Convair's 880 jet transports and Air Force F-102A jet interceptors, bonded with SCOTCH-WELD adhesives, will outlast the metal structure they bond together! In industry, too, SCOTCH-WELD adhesives are finding use in joining hermetically sealed metal shipping containers, multiple piece castings and thinner gauge metals, where tear strength would limit the effectiveness of other joining methods.

Look first to 3M! A pioneer in adhesive research, 3M has developed the widest line of adhesives in the industry. These Technical Service facilities are at your disposal. For an accurate appraisal of how an adhesive can add strength, light weight, production economy, and greater design freedom to your process or product, call your nearest 3M Field Engineer or write to: AC&S Division, 3M Company, Department SBS-31, St. Paul 6, Minnesota.

"SCOTCH-WELD" is a Reg. T.M. of 3M Co. © 3M Co., 1961.



What do you want to bond to what?

The 3M Rhino is fabricated of these materials and bonded with SCOTCH-WELD Brand Structural Adhesives:

1. Wood 2. Aluminum 3. Glass 4. Ceramic
5. Plastic 6. Permanent Magnet 7. Brass

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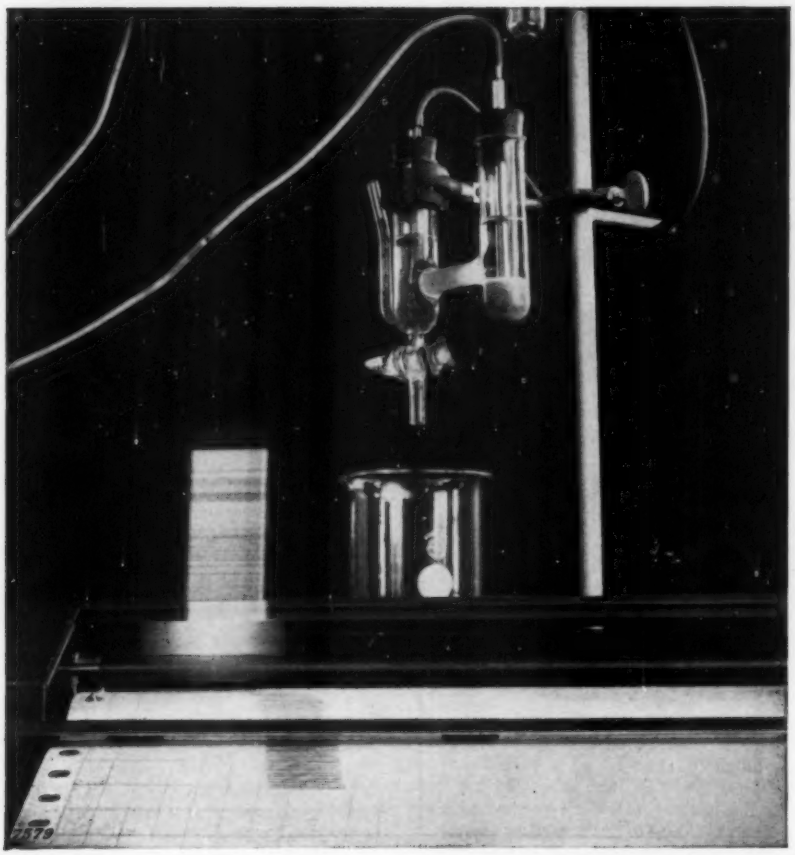
. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

ANALYTIC "BLOODHOUND" SNIFFS OUT SECRETS OF BEARING CORROSION



WE USE THIS HYPERSENSITIVE DEVICE TO TRACK DOWN ENGINE BEARING CORROSION TO ITS SOURCE. This instrument needs only a minute fragment of metal for accurate analysis. Consequently, engine bearing corrosion can be traced from its beginning through complete destruction of the bearing surface. Because test variables are minimized, Federal-Mogul engineers can accurately relate degree of corrosion to specific engine operating conditions. This analytical tool is in continual use in our laboratory, assisting research on many different projects. Prevention of corrosion and development of new bearing alloys are high on the list!

SUCCESSFUL BEARING PERFORMANCE depends on selecting the proper alloy for the operating conditions to be met. Federal-Mogul engineers have had years of experience with bearings and applications of all kinds . . . and this wealth of knowledge is available to bearings users. This is one reason why F-M sleeve bearings, precision thrust washers, formed bushings, and low-cost spacers are chosen for use in virtually everything from baby buggies to heavy industrial cranes.

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28 CIRCLE 28 ON READER SERVICE CARD

READER TO EDITOR

The Go-to-sleep Switch

To the Editor:

In the "Why Don't They R & D. . .?" column, p 32 of your Jan 23 issue, a reader proposes a sleep-switch radio in which the volume is gradually lowered. Your reader can make a very simple change in the wiring of his radio to achieve his aim. Just change the location of the on-off switch from its usual position in the grounded (chassis) side of the line to the "hot" side. The anode of the rectifier tube is fed directly from the "hot"side of the line and not through the on-off switch. When the switch is turned off it interrupts the power only to the tube heaters. The cathodes will cool down gradually, ceasing emission only after 10 to 15 seconds. Plate voltages will gradually decrease over this time until inoperative, giving the desired effect.

At least one manufacturer (Philco in its "Predicta" clock radio) provides this effect, though I haven't examined its circuit to see how it is accomplished.

—H W RENNER
Project Coordination
Development Planning, IBM
Owego, NY

Aluminum Can Take Heat

To the Editor:

The problem presented by R. J. Patton of Convair, ("Ignorance About Metals May Hold Back Supersonic Transports," Dec. 26 '60, p 9), apparently is one of communications, not lack of knowledge. Mr Patton is reported saying that sufficient information on aluminum is not available to permit building a Mach 2 supersonic transport plane. Specifically, he maintains that no data exists for strength and other properties of aluminum alloys that have been exposed to temperatures ranging from 300 to 350 F for longer than 10,000 hours.

We are interested in bringing to Mr Patton's attention some of the data recorded by Alcoa Research Laboratories during 40 years of investigating the properties of aluminum and its alloys. Data is available on the tensile properties of many aluminum alloys exposed to elevated temperatures for periods longer than 100,000 hours (11 years). Data on compressive yield strength and shear strength at elevated temperatures are less extensive, but there is substantial evidence that ratios between these properties remain nearly constant.

—E H SPUHLER, *manager*
Aerospace & Military Equipment Group
Sales Development Div
Aluminum Co of America

The Equality Myth

To the Editor:

A rousing "Hear! Hear!" for Mr Sayler's letter (Jan. 16, p 27). The widespread impression that group brain power is the answer to inventive and creative

advancement is as logical as the supposition that a mob of otherwise qualified artists should be commissioned on a group basis to produce the great art work of our time.

Our society, obsessed with the equality myth, hesitates to accept individual effort. It is much more comforting to credit a group than it is to accept the knowledge of the superiority of one individual over another. Thus, we encourage specialization and fitting into the group effort rather than encouraging the individual to work toward creation of the whole.

There may be many good things to say about the large R & D groups (i.e. their sociological and political aspects), but in my humble opinion there is very little good to say about these groups' ability to turn out optimum creations—their only saving factor is that they contain individual creative ability which hasn't been totally suppressed.

—W S Wood
Santa Ana, Calif

COMING EVENTS

MARCH

9-10 . . . . Institute of Radio Engineers with AIEE & IAS, 2nd Symposium on Engineering Aspects of Magneto-hydrodynamics, Univ of Penna, Philadelphia

12-16 . . . . American Society of Mechanical Engineers, Aviation Conference, Statler Hotel, Los Angeles

14-16 . . . . Society of Automotive Engineers, National Automotive Meeting, Sheraton-Cadillac Hotel, Detroit

20-23 . . . . Institute of Radio Engineers, International Convention, Waldorf-Astoria Hotel & NY Coliseum, NYC

20-24 . . . . American Society for Metals, 12th Western Metal Congress & Exposition, Ambassador Hotel & Pan-Pacific Auditorium, Los Angeles

27-31 . . . .Instrument Society of America, National Bureau of Standards, American Institute of Physics, Temperature Measurement and Control, Veterans Memorial Building, Columbus, Ohio.

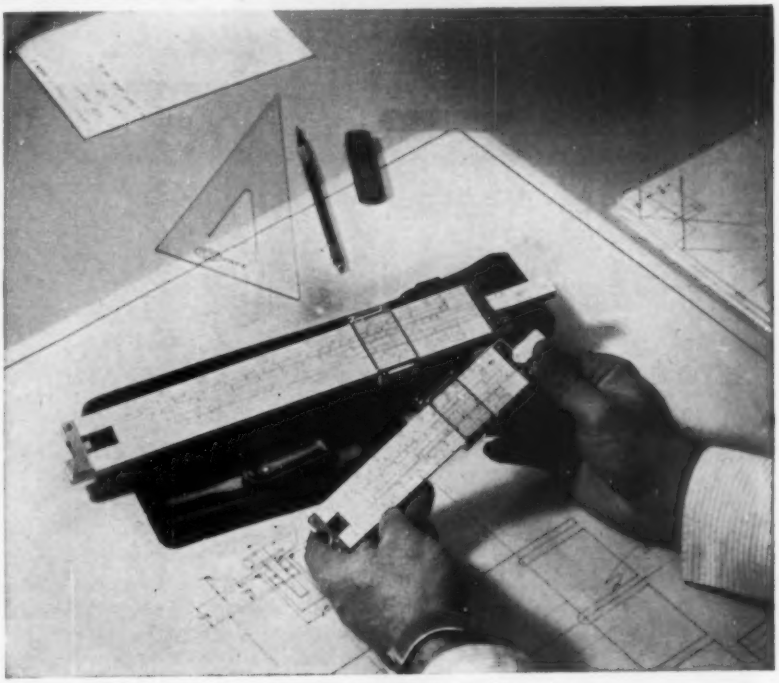
APRIL

4-7 . . . . Society of Automotive Engineers, National Aeronautic Meeting and Missiles and Aircraft Engineering Display, Commodore Hotel, New York

5-7 . . . . Institute of Environmental Sciences, Annual Meeting and Equipment Exposition, Sheraton Park Hotel, Washington, DC

For a current listing of addresses of societies and associations send 25¢ to Product Engineering Reader Service Dept, 330 W 42nd St, NY 36. Ask for brochure R 32.

DRAFTING TRENDS



This is a size comparison between the 10" POST Versalog and its 5" replica, the POST Pocket Versalog.

The trend to "COMPACT" slide rules

Why a small slide rule?

Users of America's best-selling POST Versalog, in the regulation 10" desk size, have been known to covet a 5" POST Pocket Versalog, and even buy one . . . as a more easily carried convenience . . . as a spare . . . or just for the sheer joy of having, like a gun collector, a "matched pair."

It took more than requests from pleased users of the 10" Versalog to convince our marketing people that the need actually existed for a premium-priced 5" pocket rule with 23 scales. Our technical men were even harder to convince that high Versalog standards of accuracy could be maintained in miniature.

Who can use them?

That there is a need has since been proved by the thousands of engineers, architects, scientists, and students who have bought and used a POST Pocket Versalog in preference not only to the larger version, but after comparing it with other smaller makes.

As to accuracy, we are still amazed at the exquisite job our production team has done in miniaturization—the 5" Pocket Versalog includes every one of the 23 scales found on its much larger counterpart and, in addition, bears engine-divided calibrations of such sharpness and clarity that no magnifier is needed.

Own a Versalog for less

To further popularize this fine instrument, POST dealers are offering it at a special low price for a limited time. All models come with a handcrafted leather case and spring pocket clip. Also available with hardbound instruction text.

For further information, ask your POST dealer. Or, for free literature, price data and name of nearest dealer, write to Frederick Post Company, 3642 North Avondale Avenue, Chicago 18, Illinois.

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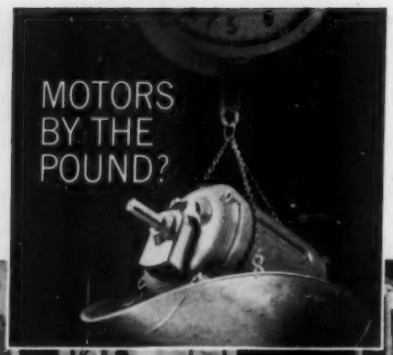
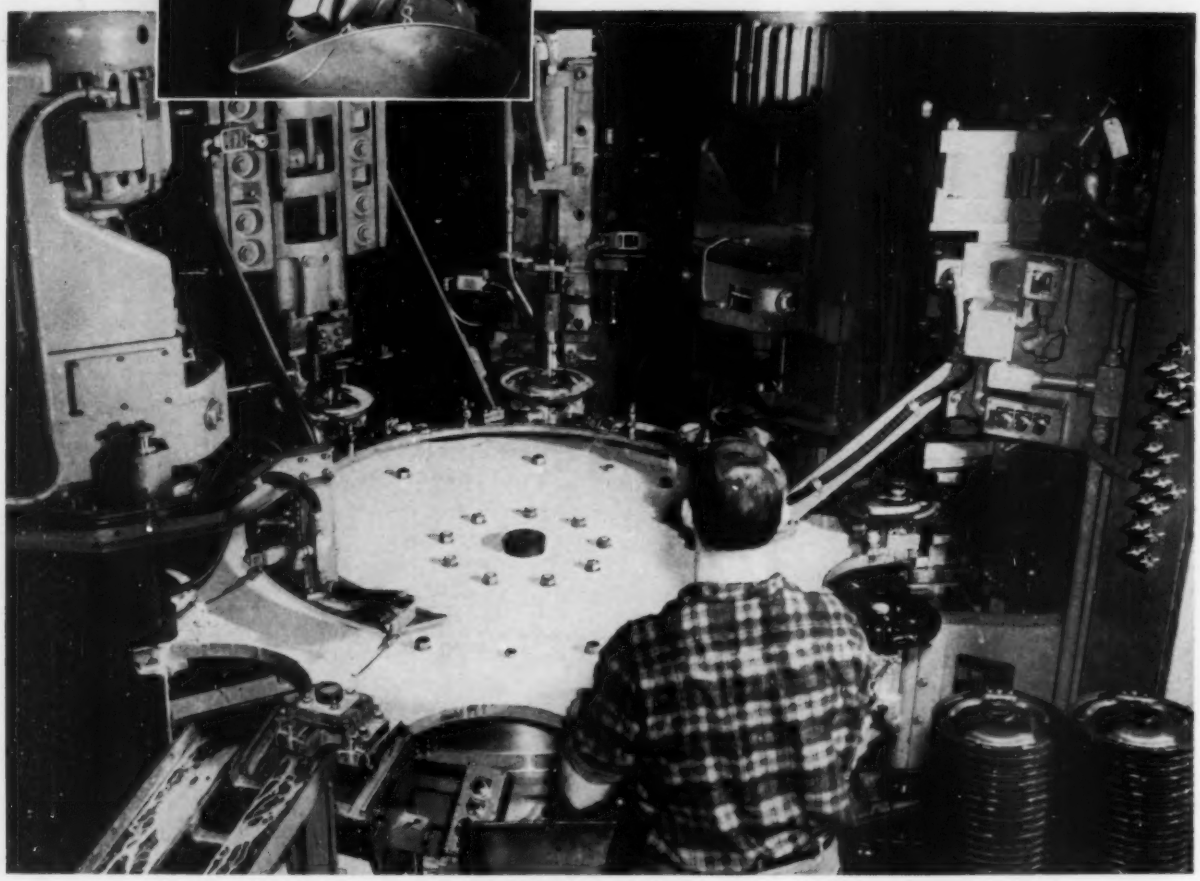


You're buying motors by the pound when price is the only consideration



Today's machine tools can't afford motors selected on the basis of price alone

Modern machine tools are designed to manufacture products of great precision at the lowest possible cost. But a machine tool is only as productive as the electric motors that drive it. Motors purchased on the basis of price alone often fail to give their users the greatest value in terms of useful service life.

The selection of the right motor to power your products requires not only specification of type, rating and operating characteristics, but consideration of such factors as uniform, troublefree performance, dependable long-life operation, the reputation of the manufacturer, and his ability to provide immediate repair parts and service—when and where they're needed. Wagner® motors have earned their reputation for proven dependability in their specific applications.

Next time you buy motors, check beyond the purchase price. Make sure that you get all the performance you need—with motors that will do the job.

Wagner motors have been getting the job done for more than 65 years. Your Wagner Sales Engineer will be glad to show you why. Call him for an analysis of your next motor application, be it for plant or product.

Branches and Distributors in all Principal Cities

Wagner Electric Corporation

6406 PLYMOUTH AVENUE, ST. LOUIS 33, MISSOURI

WM61-4

Smaller Panels

WITH SQUARE D "System-Designed" RELAYS

CLASS 8501
TYPE DO-22

Write for Bulletin D.
Square D Company,
4041 North Richards Street, Milwaukee 12, Wisconsin

• Square D relays are available for both AC and DC systems—with up to 10 contacts—in both electrically and mechanically held forms. Timing relays are also available in AC and DC versions—with timing intervals from 0.2 second to 3 minutes.

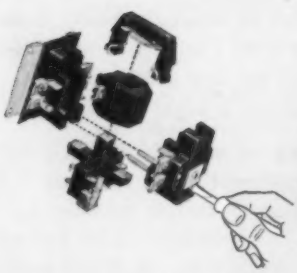
Both relays and timers give you these important advantages:

Require less panel space • Relays are only 3″ wide, range in height from 3¼″ to 5″. Timers are just 2⅝″ x 4³⁄₁₆″ or 2½″ x 7²¹⁄₃₂″. Mechanically held relays require no extra panel space.

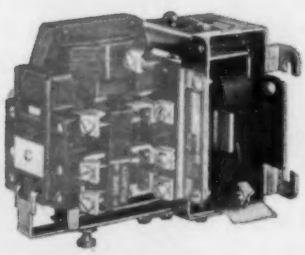
No mounting problems • All Type A timers and Type D relays have identical mounting hole dimensions.

Easy wiring • Choose either pressure wire connectors or slip-on connectors for all terminals.

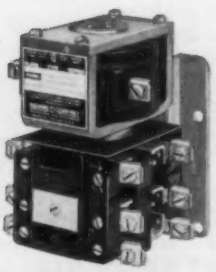
Long life • Balanced construction reduces wear on single moving part. Epoxy-resin molded coil operates cooler, virtually eliminates coil burnout.



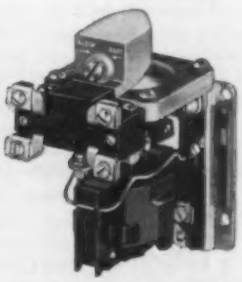
Disassembly from front in 20 seconds makes Square D Type D relays easiest to maintain



Convert any Square D Type D relay to mechanically held with easy-to-use attachment



DC relays have contact arrangements and mounting hole dimensions identical to AC



Timing relays convertible from on-delay to off-delay, using only a screwdriver

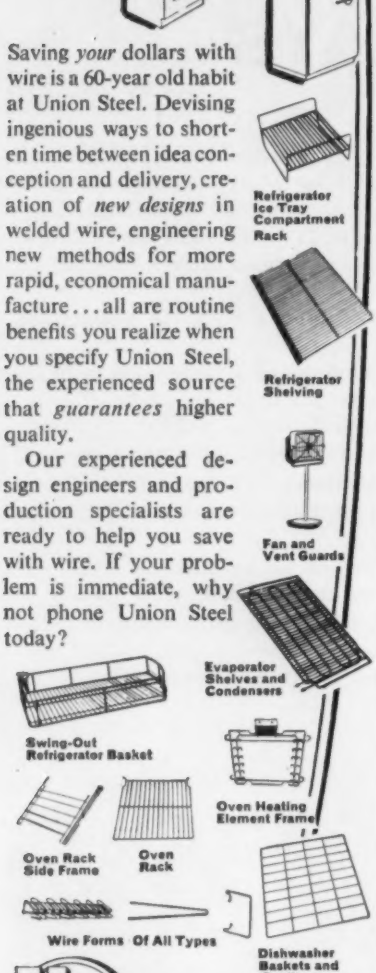
Square D offers the broadest line of relays, starters and accessories for all types of control systems

SQUARE D COMPANY

WHEREVER ELECTRICITY IS DISTRIBUTED AND CONTROLLED

Saving *your* dollars with wire is a 60-year old habit at Union Steel. Devising ingenious ways to shorten time between idea conception and delivery, creation of *new designs* in welded wire, engineering new methods for more rapid, economical manufacture... all are routine benefits you realize when you specify Union Steel, the experienced source that *guarantees* higher quality.

Our experienced design engineers and production specialists are ready to help you save with wire. If your problem is immediate, why not phone Union Steel today?



USP UNION STEEL PRODUCTS CO.
Albion, Michigan

Gentlemen: Please give us, without obligation, your suggestions for the use of fabricated and finished wire in our products.

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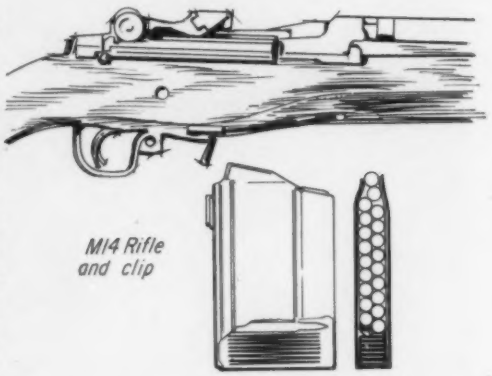
☐ Please have a USP representative contact us at once. We are interested in_____

WHY DON'T THEY R&D..?

The following suggestions are extracted from the latest (Dec '60) edition of "Inventions Wanted by the Armed Forces." If you think you have an answer to any of these problems, or if you would like a copy of this booklet, write: National Inventors Council, US Dept of Commerce, Washington 25, DC.


M14 Rifle and clip

. . . an expendable magazine for the M14 rifle. The present magazine holds 20 rounds of 7.62-mm ammunition and is loaded by feeding it 5-round clips either while it is detached from the rifle or after it is in place. Because the time to reload can jeopardize a soldier's safety, it would be preferable to have an inexpensive magazine that can be thrown away when expended. Specific requirements are: (1) 20-round capacity, (2) low cost, (3) capable of being stored, fully loaded, for at least 3 years, (10 years preferable); (4) weight, empty, less than 8 oz, (5) performance equal to present magazine. Storage problem is complicated by the magazine's spring feed; after a period of time, the spring takes a set and no longer delivers cartridges properly. One possible solution, though not suggested by the Armed Forces: design a 20-round container made of light plastic. As it is pushed in against the spring pressure, the casing splits away and is discarded.

. . . a quick-disconnect hose coupling with identical mating parts. The male and female connectors on present transfer hoses are cause of considerable confusion: frequently the hose will not have the proper connectors and an adapter will be necessary. If proper adapter can't be found, the hose is useless. The needed couplings should be made in sizes from ¼ in. to 2 in. and should withstand pressures up to 3000 psi.

. . . improved pumps for torpedos. Two types are needed. One is a lightweight pump to replace heavy fuel pumps. It must weigh less than 1 lb, pump 30 to 40 gal./min. of sea water, oxidizer or fuel at pressures up to 2000 psi, and turn at speeds up to 8000 rpm. Also needed: a quiet hydraulic pump to handle 25 hp and pressures from 1000 to 2000 psi. It should produce minimum noise in the sonic and ultrasonic (to 50 kc) band.

. . . a distinctive audio signaling device. Its warning signal should be completely unlike present sirens, horns, whistles, bells, buzzers, explosions or engines (jet or reciprocating). Size and cost should be comparable to conventional sirens and sound intensity should be at least 125 db (where reference level is 0.002 dynes per cm^2) at 100 ft.

Have you a problem, based on known scientific principles, which seems to have an answer somewhere within the limits of present technology? To inspire inventors along worthwhile paths, PRODUCT ENGINEERING invites you to trade such problems with fellow readers who have a fresh viewpoint or more time to experiment. We pay $10 for each one accepted.

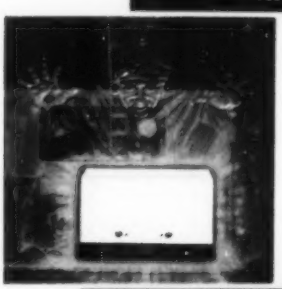
CIRCLE 33 ON READER SERVICE CARD→

hoover quality

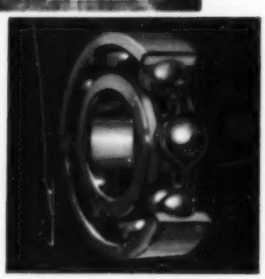
. . . CONTROLLED FROM START TO FINISH

High quality chrome alloy steel wire is produced by the Cuyahoga Steel and Wire Division of Hoover Ball and Bearing Company.

Micro-Velvet balls are produced in the Hoover Ball Division plants in Middletown, Ohio, and Erwin, Tennessee.



Hoover is actively engaged in the development of an expanded line of non-destructive electronic inspection equipment.



Hoover Quality bearings are the final result of the combined know-how of highly specialized, yet integrated Hoover divisions.

Hoover Quality, widely recognized by bearing users, is the result of complete control of every step in the manufacture of bearings.

Specialized knowledge gained through the operation of its own wire drawing mill aids Hoover in setting and controlling the quality standards of wire from which balls are made.

As America's leading producer of balls, Hoover has the experience and equipment it takes to make balls of exceptional quality. *Micro-Velvet* balls used in Hoover bearings are accurate within millionths of an inch!

And Hoover utilizes exclusive processes that assure product superiority. *Hoover Honed* raceways are super smooth, superbly finished. Testing and inspection at various stages of manufacturing are accomplished with specially designed equipment. Even non-destructive electronic inspection is employed.

Hoover Quality is the result of complete control . . . from start to finish.

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BALL AND BEARING COMPANY

5400 South State Road, Ann Arbor, Michigan

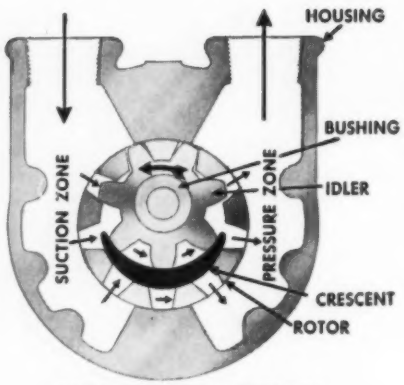
Zone Sales Offices and Warehouses	8581 South Chicago Ave., Chicago 17, Illinois 290 Lodi Street, Hackensack, New Jersey 2020 South Figueroa, Los Angeles 7, California

Micro-Velvet and *Hoover Honed* are Hoover Trademarks.

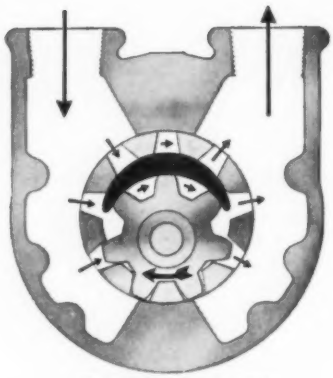
The TUTHILL Internal Gear Pump . . . and its advantages in reversing applications

by E. H. Schanzlin,
Chief Engr., Tuthill Pump Co.

Extremely high reliability, proven in thousands of applications over a 30 year period, has made Tuthill's internal gear pump an industry standard. The Internal gear construction particularly adapts itself to reversing pump applications as indicated in the sketches at right.



COUNTERCLOCKWISE ROTATION


CLOCKWISE ROTATION

How It Operates

Key elements are the rotor, idler gear and the crescent shaped partition. This crescent shaped partition, shown in heavy black, is cast integral with a moving part called the idler carrier.

In the drawing at left, power is applied in counterclockwise rotation to the rotor and transmitted to the idler gear with which it meshes. The space between the outside diameter of the idler and the rotor is sealed by the crescent. When the pump is started, there is an increase in volume as the teeth come out of mesh. This creates a partial vacuum, drawing the liquid into the pump through the suction port. The liquid fills the spaces between the teeth of the idler and rotor and is carried past the crescent to the pressure side of the pump. When the teeth mesh on the pressure side the liquid is forced from the spaces and out through the discharge port.

When shaft rotation is changed from counterclockwise to clockwise, as in the drawing at right above, the idler carrier, (including the idler gear and crescent) automatically rotates 180° through the suction zone. This changes the directional flow within the pump without changing port positions. The idler carrier rotates in a cover casting fitted with stops so that the crescent can rotate only 180° —always through the suction zone. If rotation were again reversed to counterclockwise, the crescent would swing back to its original position (shown at left above).

No valves required . . . ports remain constant

This unique construction permits positive reversing action, without any valves, and with the port positions remaining constant. In addition Tuthill's reversing pumps provide all the other attributes of internal gear construction . . . extremely high reliability, compactness, and high efficiency.

Reversing Pumps with internal gear construction pay particular dividends on applications where the pump must be driven from a reversing shaft or when machinery must be shipped without knowing the ultimate direction of the driving unit.

375 reversing pump models

Tuthill offers a complete selection of over 800 different pumps including 375 different reversing pump models for capacities from ⅓ to 200 GPM; for pressures to 400 PSI; and speeds to 1800 RPM. These include a complete selection of stripped models for incorporation into products. Specially designed housings, shaft extensions, relief valves and many other features can be developed by Tuthill's engineers to meet the requirements of specific applications.

Catalog 105 contains complete information on all Tuthill Reversing Pumps. Write today for your copy.

Typical Tuthill Reversing Pump. Model 2RC has capacity of 5 GPM operating at 100 PSI, 1200 RPM.

Tuthill manufactures a complete line of positive displacement rotary pumps in capacities from 1/3 to 200 GPM; for pressure to 300 PSI; speeds to 3600 RPM.

PUMPS FOR YOUR PURPOSE

TUTHILL PUMP COMPANY

963 East 95th Street, Chicago 19, Illinois

Is your materials-handling equipment years ahead of your engineering design equipment?

Save all the money you can with the latest materials-handling devices—but don't overlook your drafting department, either! Professional draftsmen really deserve the latest equipment—it's just *good business* for you to see that they have it.

Your draftsmen, your productivity, deserve new Hamilton space- and time-saving equipment from Bruning

Top engineers or draftsmen do their very best work at peak efficiency—when they work with high-quality, *professionally designed* equipment. It's a morale-boosting compliment to a good man to give him the *best* equipment. He feels better, works harder, makes fewer errors. And the genuine quality in each Hamilton unit will actually save real money over the years. Why not gain the plus benefits of modern styling at a modest investment—plus the better working atmosphere Hamilton units provide? Our planning engineers are as close as your phone!

HAMILTON CL-100 TABLE Entirely new, canted-leg styling assures stability without side crossrails. Strata-Core board, with green linoleum surface, both sides steel edged; tilts 0° to 40°. Fully adjustable recessed footrest; steel reference, tool, and catalog drawers. Other fine features, superb styling in light Sahara Tan, satin-chrome hardware.

Hamilton L-Contour Table
Prestige-assured, individualized work area providing complete board adjustment plus extra storage and reference area.

Hamilton Unit System Files
Provide full protection, accessibility, and classification for all materials to be filed. Occupy minimum floor space.

Hamilton Auto-Shift Table
Built-in mechanism adjusts board to individual height and slope requirements, provides full accessibility, reduces errors.

Put draftsmen in a "position" to do better, faster work!

Bruning's all-new Neoglide drafters literally help draftsmen straighten up and do faster, better work.* They provide complete maneuverability on any board at any angle without adjustment! Reinforced U-beam construction assures rigidity, strength, and accuracy. Resistance-free movement of vertical beam and hidden counterweight provide fast "floating" action.

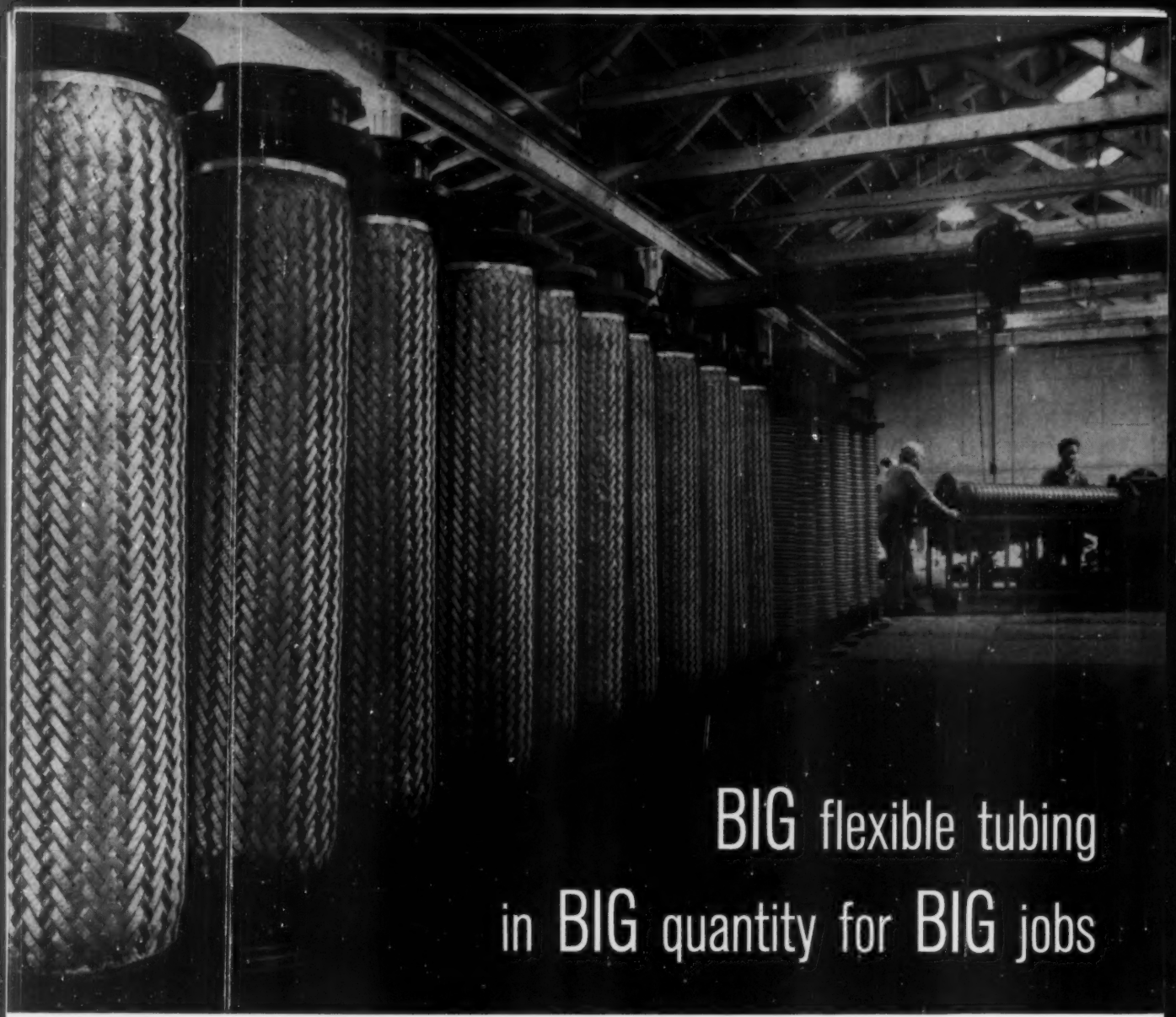
Touch-control protractor head gives automatic, pinpoint angle selection.

*Study of 300 draftsmen showed 35% savings in drawing time—1/5 the backaches—on vertical or near vertical boards.

BRUNING

CHARLES BRUNING CO., INC.
1800 CENTRAL RD., MT. PROSPECT, ILLINOIS

CIRCLE 35 ON READER SERVICE CARD



Whatever your flexible metal tubing problem, Anaconda's broad design and manufacturing capability can make your job easier

The big corrugated stainless steel tubing assemblies shown above were designed and manufactured by Anaconda Metal Hose for water lines in the missile program. Construction of these 12″ I.D. lines is corrugated stainless steel flexible tubing, reinforced with stainless steel wire braiding; end fittings are floating flanges. This type of tubing can also be produced in other metals as Bronze, Steel, in standard ID's through 16″ and standard lengths of 20 feet.

Small flexible tubing for small tough jobs, too. At the other end of the scale are tiny ⅛″ Vibration Eliminators. And in between, the variety of flexible hose assemblies — in size, material, and design — is almost infinite.

Sales Engineering Consulting Services that follow through from original design to finished product. Simply let us know your needs, with conditions, dimensions, and such sketches and drawings as might be necessary to give us an understanding of your problems. We will work out design problems with your engineers and draftsmen. We will manufacture the flexible connectors. And we will make specialists available for immediate service calls on equipment or field installations. These services are available through our representatives in leading cities—see listing "Hose-Metal" in the Yellow Pages. Or write: Anaconda Metal Hose, Box 791, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

60127

ANACONDA®
Metal Hose

PRODUCT ENGINEERING HORIZONS

March 6, 1961

Can a computer replace YOU?

Courses in machine design have been practical—follow the traditional approach by selecting properly rated shelf items from catalogs, calculate stress with simplified formulas, use standard values for physical properties and select empirical values for constants not readily obtainable by mathematical analysis. This is what most design engineers did at work, so it must be sound.

Further, it was taught by a group of specialists who might or might not be—or be called—designers. The emphasis was on how to use a handbook or catalog, how to calculate a stress, how to select components. The course weltered in routine, and the able student was bored stiff with it.

All right, say the educators, *we'll abandon the subject; it can't be properly taught in college anyhow.*

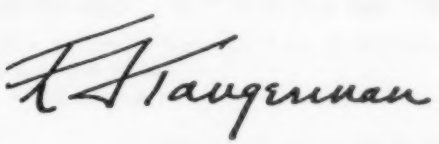
Industry should be vitally interested in this whole problem. Somebody has estimated that a draftsman capitalizes at $150,000, an engineer at $250,000 in modern business. At these rates, management can afford a fairly sophisticated machine to save routine computations and decisions. And such equipment, incidentally, will do much to remove the boredom and inefficiency that so many creative engineers complain about.

Perhaps the sound place to start this minor revolution is in the engineering college. Provide the mechanized aids as fast as they are developed. Teach the coming generation how to deliver the new idea from the mind of its creator to a punched tape or a wire or a memory, without the common transfer via draftsman and mechanic, each transfer adding more "noise" to the system.

The process might enable the college to re-integrate its teaching, making the whole engineering faculty again a part of the teaching group. It may also have the effect of making constantly useful all the training of earlier years, by presenting problems in design of heat-exchanging systems, electromechanical energy converters, hydro-pneumatic controls, automatic and electronic instrumentation—not the design of a punch press or a one-cylinder steam engine. The emphasis will be off simple components; it will be on systems and system interaction.

This will of course stretch the student's mind, force him to think with all the tools he has available, rather than to perfect himself in the use of a handbook. There'll be more falling by the wayside rather than less, we fear, but those who don't fall will be thinkers rather than punched cards.

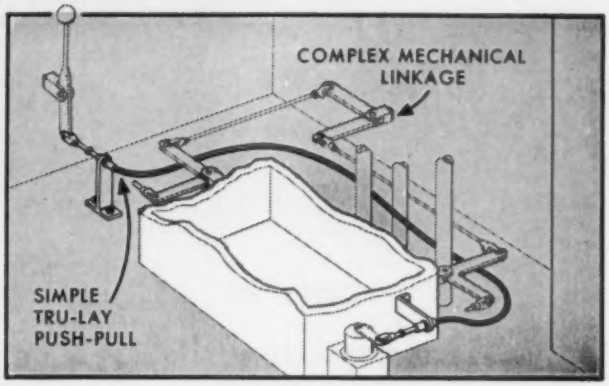
The day of the machine designer, as such, is rapidly entering its twilight. Computers and other recall devices can now do most of the work faster and more accurately. Handbook and catalog data can be programed so a machine can do handbook engineering faster and cheaper than a man. But in areas of judgment, intuition and forward thought, the computer bogs down. This is the future major field for the engineer.



← CIRCLE 36 ON READER SERVICE CARD

TRU-LAY *PUSH*-PULL CONTROLS PROVIDE ACCURATE, DEPENDABLE REMOTE CONTROL FOR HUNDREDS OF PRODUCTS

• If your products involve remote control—electrical, hydraulic, pneumatic or direct—TRU-LAY PUSH-PULL FLEXIBLE CONTROLS can help solve your design problems. They provide positive remote control over long or short distances—up to 150 feet from the control point. Because they operate while flexing, they can snake around obstructions. They will not buckle. They are ruggedly constructed, easily installed and operated, sealed against dirt and moisture, and will handle jobs with as much as 1,000 lbs. input. PUSH-PULL CONTROLS are simple, have but one moving part, are noiseless, and give a lifetime of accuracy. Mechanical linkages, on the other hand, are complex. Unlike PUSH-PULL CONTROLS, they are made of many parts, wear at many points, and produce increased backlash, lost accuracy, and vibration rattles.



Sizes and Operating Heads to Fit Your Design

Control Dimension	Minimum Recommended Radius in Inches	Maximum Input Load in Pounds (Dependent on Travel)
3/32"	2	30
1/8"	3	65-125
3/16"	5	115-175
1/4"	6	300-600
5/16"	8	700-1,000

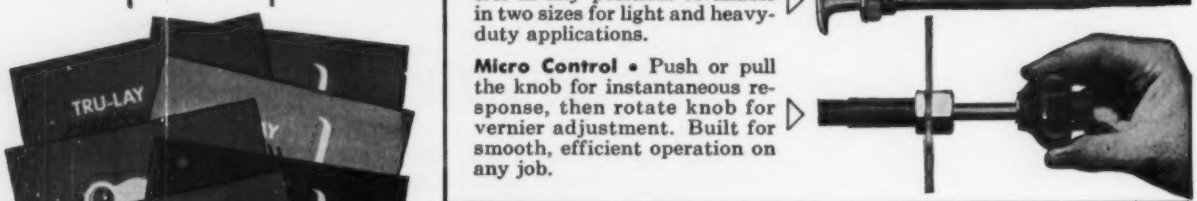
Heavy Duty • For use where rugged duty prevails, but where operation must be smooth and accurate. Meets all requirements for dependability and life.

Light Duty • Gives smooth, accurate and dependable performance at low cost. Available with your choice of several types of knobs.

Selective Friction • Amount of friction can be changed to meet individual requirements of the operator or application. Friction constant at any setting.

Position Lock • A slight turn of the T-type handle locks the control in any position. Available in two sizes for light and heavy-duty applications.

Micro Control • Push or pull the knob for instantaneous response, then rotate knob for vernier adjustment. Built for smooth, efficient operation on any job.



PUSH-PULL DATA FILE shows how to simplify, improve design

PUSH-PULL CONTROLS are solid as a rod and flexible as a wire rope. They're factory-lubricated for life, unaffected by temperature extremes, and can be adapted to practically any application. For complete details on how you can use them, write for the PUSH-PULL DATA FILE. It contains 7 engineering Bulletins which describe in detail the operation of PUSH-PULL CONTROLS, their applications, features and advantages. Our engineers will be glad to help you make TRU-LAY PUSH-PULL CONTROLS a part of your product.

PUSH-PULL CONTROLS

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ACCO

PRODUCT ENGINEERING

how to choose

THE RIGHT SOFT SOLDER ALLOY

In a previous article (PE-June 13, '60) the author explained how to select the correct solder flux for the job. Now he focuses on the solders themselves—comparing the 28 basic types and showing how to select them for your design problem. A forthcoming article will deal with soldered electrical connections.

HOWARD H MANKO
Senior associate metallurgist
Product Development Laboratory
Data Systems Div, IBM, Poughkeepsie, NY

If a production drawing for a soldered assembly contains the note "To Be Joined by Soldering," the result is hardly likely to be either a quality product or a reliable one. Such a note evades your responsibility to tailor a soldered joint to the application, and means you have not checked all the vital factors: base metal selection, precleaning and fluxing, soldering methods, post-cleaning and inspection, and–above all–selecting the solder alloy itself. This article gives the information you need to make the correct choice.

Matching Solder and Base Metal

Whatever you are joining, the base material must be solderable, even if it is being favored for its mechanical or electrical properties. Further, it must be compatible with the solder alloy selected. Table I (next page) covers these two factors. The solderability rating is self-explanatory, but compatibility has two facets not immediately discernible. First of these is **thermal compatibility** as indicated by the expansion coefficient: if the coefficients of base metal and solder differ sharply, temperature changes can easily cause excessive strain, loss of tolerance, or buckling of thin sections near the joint.

Corrosion compatibility is the second problem. Because a solder joint brings together dissimilar metals (base metal and solder alloy), galvanic corrosion can easily occur in moist environments. Seriousness of this problem depends on relative positions of the base metal and the solder's main alloying element in the electromotive series. The second column of Table I (next page) shows these for the metals commonly involved in soldering situations–those most frequently used in the solder itself are shown in bold type. The closer that the base metal and solder metal are in the series, the less chance of galvanic corrosion.

Both solderability and corrosion compatibility here refer to joints made from bare metals. In problem applications, the base metal can be coated with an intermediate fusible metal that is more easily solderable. This can be applied by hot-dipping or by plating, on either the entire part or only on the specific soldering area. Under corrosive conditions, the best procedure is to coat the entire soldered assembly–thus exposing a uniform metal surface to the corrosive environment.

Properties of Solders

The choice of solders extends far beyond the familiar tin-lead alloy system. Table II (p 42) lists a series of these fusible alloys that cover the melting range from 117 to 600 F. (This melting temperature range includes most commonly specified soft solders. Brazing takes over above 800 F). Combinations of tin, lead, bismuth, antimony, cadmium and silver—these soft soldering alloys are not the only ones suitable for this temperature range. They will, however, take care of most structural and electrical soldering jobs, they are readily available, and experience has shown them to be reliable.

Listing is in order of increasing melting temperatures. Most are solders with desirably narrow temperature range from liquid to solid, or are eutectic alloys (see "Metallurgy of Solder," p 41). Only liquidus temperature is listed for the eutectics, because for these, solidus and

REPRINTED—Circle 591, inside back cover

liquidus temperatures are identical. This method of listing makes the eutectic alloys easy to find. Keep in mind that for best soldering, temperature of the solder should be 60 to 150 F above liquidus, depending on time of soldering and cooling capacity of the assembly. This increment of temperature gives the solder fluidity and good wetting characteristics.

Once several solder candidates for the job have been selected on the basis of compatibility with the base metal, then the major factor affecting choice is the temperature the assembly can tolerate. The parts or their surroundings may distort, buckle, discolor, char or anneal excessively as a result of the soldering operation. Reference to the melting range column of Table II will indicate the best choice. Should the lowest temperature solder be unsatisfactory because of other property deficiencies, hazards of overheating can be circumvented in three ways: put a heat sink near the joint to conduct heat away from sensitive parts; interpose a heat barrier (as in torch soldering); or preheat the entire assembly as much as possible to avoid high thermal gradients. For consecutive, adjacent joints, the first solder alloy must have a solidus temperature above the soldering temperature of the second alloy ("piggyback" soldering).

With thermal-damage problems settled, the following properties in the table need your appraisal:

Mechanical strength of solders is extremely low, compared with the base metals being joined. Further, solders tend to be ductile. Although its low strength makes the solder the weakest link in the assembly, specifying sufficient bond area or mechanical reinforcement will compensate. High ductility of solders, though a disadvantage in maintaining tolerances under load, can serve to absorb excessive strain in many assemblies. Keep in mind that mechanical properties depend, to a degree, on method of sample preparation and method of test, so a certain amount of variation is to be expected between the values in Table II and those appearing in vendor literature. Ranges have been given where a confident choice of a single value for the table could not be made.

Electrical conductivity, or electrical resistivity, is important factor in all cases where the solder joint is part of an electrical circuit. The problem is to ensure enough current-carrying capacity in the solder joint, compared with the conductor itself, so that there will not be hot spots that might melt or weaken the joint. The table lists conductivity of solders in two ways; as a percent of the conductivity of the International Annealed Copper Standard (IACS), and as resistivity—the resistance (in micro-ohms) of a specimen 1 cm long and 1 sq cm in cross-sectional area. Since most electrical conductors are copper, the percent IACS is the more common expression. How to apply this and other electrical data to the design of solder electrical connections will be covered in a forthcoming article.

Coefficient of thermal expansion provides the simplest check on mechanical compatibility of solder and base metal. Ideally coefficients should match. Dimensional stability is concerned here, too, because the expansion coefficient of the solder might be from 2 to 4 times more than that of the base metal. Both problems are particularly important when soldering to fired surfaces on ceramic materials, where the bond is usually brittle. Although the table reflects our lack of thermal-expansion data on solders, these values do not vary widely among the various types. A fair guess can accordingly be made for any solder from the data presented here. A special word about bismuth-containing solders: these alloys expand upon cooling, owing to a metallurgical change that has nothing to do with normal thermal-expansion characteristics. After a certain aging period, no further change occurs. Details on this growth problem are available from bismuth-solder manufacturers.

Density data is included because it is most difficult to match density of base metal and solder in a joint. The density disparity can thus have considerable influence in designs that require accurate weight balance for correct operation (see "A Working Example," p 46). In large assemblies needing many joints, the weight of solder can become an appreciable percent of the total.

Design Considerations

Although the solder is inherently weaker than the base metal, it does not have to be the weakest link in the assembly. If the relatively low tensile and shear strengths of a solder are utilized efficiently by clever design, joints

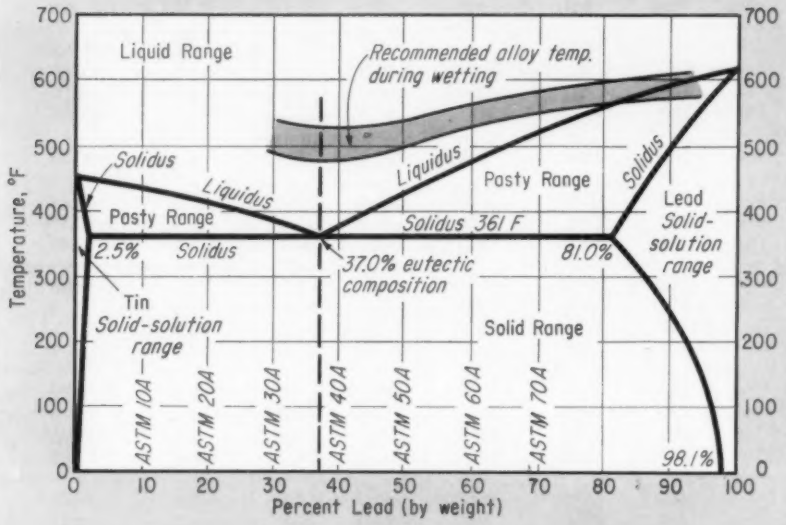
text continued, page 42

I—SOLDERABILITY OF METALS

1 = Normally soldered
2 = Soldered only under special conditions
3 = Not normally soldered

Metal	Electromotive potential, volts	Solderability	Melting Point, °F	Expansion coefficient in./in./°F × 10^{-6}
MAGNESIUM	+2.34	2	1204	14.3
BERYLLIUM	+1.70	3	2343	6.9
ALUMINUM	+1.67	2	1215	13.3
ZINC	+0.76	1	787	18.0
CHROMIUM	+0.71	3	2822	4.5
IRON	+0.44	1	2795	6.6
CADMIUM	+0.40	1	610	16.6
INDIUM	+0.38	1	314	18.0
COBALT	+0.28	3	2714	6.7
NICKEL	+0.25	1	2645	7.6
TIN	+0.14	1	450	13.0
LEAD	+0.13	1	621	16.0
HYDROGEN	0.00	—	—	—
STAINLESS	−0.09	2	2550	9.2
ANTIMONY	−0.10	1	1166	6.3
BISMUTH	−0.20	1	520	7.5
SILICON	−0.26	3	2588	4.1
COPPER	−0.34	1	1981	9.1
STEEL	−0.58	1	2760	6.7
SILVER	−0.80	1	1761	10.5
PALLADIUM	−0.82	1	2829	6.6
PLATINUM	−0.86	1	3224	4.3
GOLD	−1.68	1	1945	8.0

METALLURGY OF SOLDER AND ITS EFFECT ON DESIGN



■ The phase diagram, or equilibrium diagram as it is sometimes called, shows the temperatures at which any specific solder alloy changes phase from solid to liquid or vice versa. Diagram sketched above is for the tin-lead system as an example. Abscissa shows percentage of one of the two constituents in the alloy, in this case, lead. Ordinate gives the temperature for the various changes. Several distinct areas can be found on the diagram as follows:

Liquid region is one where the alloy at all compositions is completely fluid, separated from areas that contain solid constituents by a line called the liquidus. A specific alloy composition heated to the liquidus temperature becomes completely fluid. This temperature is not necessarily suitable for soldering purposes. The band above the liquidus indicates the recommended temperature-range within which the solders are used in everyday applications. This higher temperature is necessary to ensure proper flow of the solder and to take care of all heat losses to cooler surfaces being wetted. In special cases, soldering can be accomplished close to the liquidus temperature.

In the pasty, or semiliquid region, one part of the alloy has frozen out of the melt and a mushy substance is the result. This phase contains both molten and crystalline metal. The crystalline content in the mixture determines its viscosity and flow characteristics. Sometimes it is very desirable to work in this region—in solder wiping, for example. However, the solder worked in this region usually does not have a smooth appearance. This region's lower limit is the solidus line. In systems where there is a eutectic composition (see below) this is a straight line, and is therefore sometimes termed the eutectic line. For the tin-lead system shown, this line is at 361 F.

Solid range covers all points where the solder joint may be considered completed. The two regions set off on both sides of the solid area—termed solid-solution regions—have special physical and metallurgical characteristics. However, it is very seldom that these regions are used for soldering purposes as their melting points are much higher than the eutectic temperature. Occasionally, on fast cooling, the solidus temperature can be passed so that liquids are found in temperatures lower than the solidus. However, this is simply a non-equilibrium condition of little importance in practical cases.

Eutectic composition is not a true region, but is represented in this diagram only by a dashed line. In tin-lead the eutectic composition is around 63% tin and 37% lead; however, this percentage has not been definitely established and slightly different values are reported. At the solidus temperature the solidus and liquidus regions meet, which means that the eutectic alloy has a sharp point of demarcation between the solid and liquid states. This is very desirable for solder purposes because the alloy does not go through the pastry range: joints become rigid quickly upon cooling. In addition, every alloy of this composition has other desirable soldering characteristics: mobility is a maximum, and resistivity and metallurgical structure are extremely uniform. This composition is unique with each alloy system and the eutectic solders are widely used in the soldering field.

How do these regions affect the choice of a specific solder for a specific job? The answer is simple: You have to make sure the joint design does not leave any possibility of movement while the solder is in pasty stage. Such movement results in the unwelcome "cold-solder" joints identified by their frosty look. At the worst, these joints can be "fractured" joints. If the joint cannot be secured against movement during cooling, a solder with a small pasty range should be specified —preferably a eutectic composition. However, if the solder must be worked —as in wiping—then a solder with a wide pasty range should be selected. Again, this information is available from the phase diagram for that alloy system.

All the above considerations are true and useful for binary alloys. For an alloy with more than two constituents a different type of phase diagram must be constructed—a refinement not considered here. However the concepts of soldus and liquidus, eutectic and solid solution hold true for any alloy system, regardless of the number of constituents. Solder manufacturers will usually supply phase diagrams upon request. ■

II—PROPERTIES OF RECOMMENDED SOFT SOLDER

No.	ALLOY COMPOSITION, percent							MELTING TEMPERATURES, °F		MECHANICAL PROPERTIES				PHYSICAL	
	Sn	Pb	Bi	In	Sb	Cd	Ag	Solidus	Liquidus	Tensile strength,[1] psi	Shear strength,[1] psi	Elongation, %	Hardness, BHN	Electrical conductivity, % IACS	Electrical resistivity, microhm-cm
1	8.3	22.6	44.7	19.1	—	5.3	—	—	117	5400	NA	1.5	12.0	3.3	51.62
2	12.0	18.0	49.0	21.0	—	—	—	—	136	6300	NA	50.0	14.0	3.0	57.47
3	13.3	26.7	50.0	—	—	10.0	—	—	158	5990	300[2]	200.0	9.2	4.0	43.10
4	12.5	25.0	50.0	—	—	12.5	—	158	165	4550	NA	30.0	25.0	3.1	55.61
5	11.3	37.7	42.5	—	—	8.5	—	160	190	5400	300[2]	220.0	9.0	4.3	40.38
6	50.0	—	—	50.0	—	—	—	—	243	1720	1630[2]	83.0	4.9[4]	11.7	14.74
7	37.5	37.5	—	25.0	—	—	—	—	280	5260	4300[2]	101.0	10.2[4]	7.8	22.10
8	42.0	—	58.0	—	—	—	—	—	281	8000	500[2]	200.0	22.0	5.0	34.48
9	—	15.0	—	80.0	—	—	5.0	—	314	2550	2150[2]	58.0	5.2	13.0	13.26
10	—	—	—	100.0	—	—	—	—	314	515	890[2]	41.0	Too soft	24.0	7.18
11	70.0	18.0	—	12.0	—	—	—	302	345	5320	4190[2]	135.5	12.0[4]	12.2	14.13
12	63.0	37.0	—	—	—	—	—	—	361	7700	5400	28–30[5]	17.0	11.5	14.99
13	70.0	30.0	—	—	—	—	—	361	367	7800	5000	20.0	17.0	12.5	13.79
14	60.0	40.0	—	—	—	—	—	361	370	7600	5600	27–40[5]	16.0	11.5	14.99
15	50.0	47.0	—	—	3.0	—	—	365	399	8400	6850	29.0	15.6	9.6	17.96
16	50.0	50.0	—	—	—	—	—	361	417	6200	5200	38–98[5]	14.0	10.9	15.82
17	—	50.0	—	50.0	—	—	—	—	419	4670	2680[2]	55.0	9.6[4]	6.0	28.74
18	96.5	—	—	—	—	—	3.5	—	430	2860	NA	73.0	40.0	14.0	12.31
19	—	—	—	90.0	—	—	10.0	—	448	1650	1600[2]	61.0	2.7[4]	22.1	7.80
20	—	75.0	—	25.0	—	—	—	—	448	5450	3520[3]	47.5	10.2[4]	4.6	37.48
21	40.0	60.0	—	—	—	—	—	361	460	5400	4800	39–115[5]	12.0	10.1	17.07
22	95.0	—	—	—	5.0	—	—	452	464	5900	6000	38.0	13.3	NA	NA
23	95.0	—	—	—	—	—	5.0	430	473	8000	NA	30.0	13.7[6]	12.6	13.70
24	20.0	80.0	—	—	—	—	—	361	531	4800	4200	22.0	11.0	8.7	20.50
25	90.0	—	—	5.0	—	—	5.0	—	554	5730	3180[2]	23.0	9.0[4]	5.6	30.79
26	—	97.5	—	—	—	—	2.5	—	579	4400	2900	42.0	Too soft	8.8	19.50
27	1.0	97.5	—	—	—	—	1.5	—	588	4420	NA	23.0	9.5	NA	A
28	—	95.0	—	5.0	—	—	—	—	599	4330	3220[3]	52.0	6.0[4]	5.1	3^.80

[1] Ultimate stress alloy alone, except; [2] Recommended working stress in joint; [3] Ultimate stress in joint. [4] Modified BHN using 100-kg load, ½ min.

of high reliability can be made. Here are the main factors to consider, once the solder and base metal have been selected:

Joint geometry determines how loads are transmitted from one member to the other in mechanical joints, or how well current flows in electrical joints.

For mechanical joints, the following configurations merit consideration:

Butt joints are the simplest, but also the weakest because the soldered interface is limited to the cross-section of the part. This requires great uniformity in the finished joint. Adding a strap to one side of a butt joint will provide additional strength.

Scarfed joints are butt joints cut on the bias; this increases interface area and introduces shear as a means of distributing the load. Though rare in soldered assemblies, the scarfed joint can be introduced as a locating method—because of its wedging characteristic—in complicated assemblies.

Lap joints are most commonly specified in soldering because added strength is quite easily supplied by increasing the lap area. Single-lap joints are simplest, but subject to bending under axial loads. In serious cases, a double-lap joint solves this problem.

Sleeve joints combine butt joint and lap joint in a configuration of circular symmetry. This very strong joint is most often employed where combination loads are present —as in piping, shafts, and certain electrical connections. As in lap joints, strength is easily adjusted.

Mechanically reinforced solder joints are often needed when the solder selected is of low strength and when space limitations will not permit strengthening with a scarf, lap or sleeve joint. To reinforce, shape the base metal (as in interlocking, wrapping or keying), or add stiffeners (such as rivets, pegs, or bolts).

For electrical connections, the major problem is to keep the soldered joint from being the weakest electrical link; here, mechanical security, though important, is secondary. Joint configurations include variants of butt and lap joints, plus several hook-on and wrap-around styles. How to select

ALLOYS (in order of increasing liquidus temperature)

PROPERTIES Expansion coefficient (in./in./°F) × 10⁻⁶	Specific gravity	GENERAL NOTES	Common Tradenames	Approx. Cost, $/lb[7] (500-lb lots)	No.
13.9	8.86	Expands, then shrinks to zero in 30 min.	Cerrolow—117	8.7	1
12.8	8.58	Expands, then shrinks to zero in 60 min.	Cerrolow—136	9.4	2
12.2	9.38	Expands to 0.0057 in./in. permanently	Cerrobend	3.1	3
NA	9.50	Nonelectrical solder for low-ambient temps	Woods Metal	4.0	4
NA	9.43	Shrinks to 0.0025 in./in., then expands to zero in 60 min.	Cerrosafe / Indalloy—1	2.7	5
NA	7.74	Low vapor pressure; good for glass	Cerroseal—35	18.0	6
NA	8.97	Very good resistance to alkaline corrosion	Indalloy—5	10.0	7
8.3	8.72	Expands to 0.0007 in./in., then shrinks to 0.0005 in./in.	Cerrotru	3.8	8
NA	8.20	Good for thin precoat on ceramics	Indalloy—2	28.5	9
18.3	7.44	Expensive, bonds to nonmetallics	Pure Indium	34.3	10
NA	7.96	Good strength, low-cost indium alloy	Indalloy—9	6.3	11
13.7	8.46	Used where pasty range is intolerable	Eutectic Sn-Pb	0.8	12
12.0	8.17	Good pre-tinning alloy	ASTM 70A	0.9	13
13.3	8.52	Good electrical-grade solder	ASTM 60A	0.8	14
NA	8.75	Similar to 50–50 Pb-Sn, resists creep well	ASTM 50C	0.7	15
13.0	8.90	General-purpose solder	ASTM 50A	0.7	16
NA	9.14	Very good resistance to alkaline corrosion	Indalloy—7	18.5	17
NA	10.38	High temp, electrical solder for instruments	Eutectic Sn-Ag	1.8	18
NA	8.10	Solders silver, fired glass and ceramics	Indalloy—3	32.5	19
NA	9.80	Very good resistance to alkaline corrosion	Indalloy—10	10.0	20
13.9	9.28	Good wiping solder	ASTM 40A	0.6	21
15.0	7.20	Lead-free, used in food equipment	Food solder	1.5	22
NA	NA	High-temp electrical solder	Instrument solder	2.1	23
14.7	10.04	Cheap solder for body work and plumbing	ASTM 20A	0.5	24
NA	11.30	Lead-free indium solder	Indalloy—12	3.5	25
NA	NA	Torch solder, poor corrosion resistance	ASTM 2.5S	0.8	26
NA	11.28	Slightly better corrosion resistance than No. 26	ASTM 1.5S	0.7	27
NA	11.35	Zinc-free indium solder	Indalloy—11	2.5	28

[5] Depends on specimen preparation. [6] VPN. [7] as of Dec. 1960. NA = Not available.

among these and to design them for adequate current-carrying capacity is the subject of the next article in this series.

Clearance between interfaces being joined influences strength. Experiments show that maximum strength, sometimes higher than the solder alloy itself, is developed at about 0.003-in. clearance, where both flux and solder can flow easily into the joint to give uniform wetting. Below this, gases and flux may be trapped so that wetted area, and thus joint strength, is reduced. Larger spacings interfere with capillary action necessary for good wetting and flow into the joint.

Identify the weakest link in the joint. Normally the solder itself is weakest because the metallic interface is an alloy of both the solder and the base metal. However, intermetallic compounds (*PE—June 9 '58, p 72*) can form between constituents of the base metal and of the solder alloy. These compounds can be brittle and, when they congregate at the interface, will lower its strength, so that it becomes the weak link. Table III (p 45) lists the number of intermetallic compounds that can occur in soldering applications.

Prolonged loading is apt to cause creep in the solder, even if the stress set up is well below the solder yield strength. Creep occurs more readily near recrystallization temperatures, which are very low for most fusible alloys —in some cases near room temperature. In creep situations, reinforce the solder joint, or specify brazing (soldering with alloys that fuse above 800 F) or welding. Detailed creep data is often available from the manufacturer.

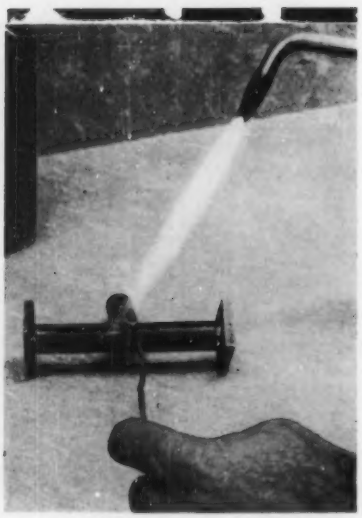
Safety factors for soldered joints are not clearly established because too many variables interact: solderability of base metal, flux, solder alloy, solder method, time-temperature cycle, etc. As long as stress concentrations are avoided, safety factors can be based on such factors as the reliability required and operational abuse to be encountered. If a localized stress cannot be avoided, build in extra flexibility at this point to redistribute the stress. Further detail on safe design of soldered joints may be found in: *Soldering Manual* published by American Weld-

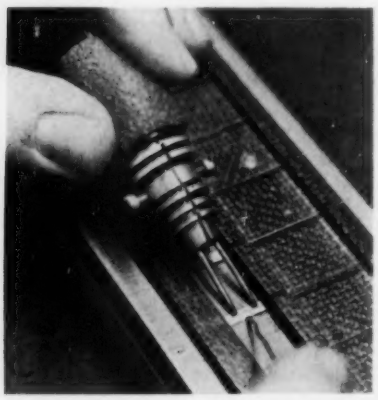
7 SOLDERING METHODS AVAILABLE

1 . . SOLDERING-IRON is primarily a manual heat source useful for short-run applications or hard-to-reach joints. Keep iron several hundred degs above soldering temperature; this gives enough reserve to bring workpiece up to temperature quickly. A clean, tinned tip aids conduction of heat to workpiece—repeated wiping or fluxing is essential.

2 . . TORCH SOLDERING has advantage of heating large masses quickly to temperature. As with soldering-iron, heat is supplied to the largest mass present to build up a thermal reservoir. Both methods depend much on operator skill, are not well-suited to large-production runs where maximum uniformity of joint quality is essential. Torch heating is difficult to localize, should not be specified if assembly parts are heat-sensitive.

3 . . RESISTANCE SOLDERING utilizes the electrical resistance to generate heat in the workpiece. Electrode resistance iron shown here is one of a number of tools designed on this principle. Chief advantages: it's faster than soldering-iron or torch methods, and the heat generated can be localized. Though unsuitable for high-speed automated production, this method is often specified for medium-production runs.





4 . . FURNACE SOLDERING reduces number of variables in joining process, gives high degree of uniform-quality joints. Preassembled joints containing parts, flux and solder preform are fed through the furnace on a carefully predetermined schedule of temperature and time. This technique, employing either gas-fired or electrically heated ovens, is well-suited for automatic production and large quantities. Local heating, however, impossible.

ing Society and *Notes on Soldering* published by Tin Research Institute.

Writing the Specifications

The 11 points listed below should be carefully checked for inclusion on the design drawing for any soldered joint. These points are not intended as actual soldering instructions. Rather, they ensure that the joint will function as designed, by giving guidance to the production engineer who then draws on past experience for the step-by-step soldering sequence. In effect, these are the vulnerable points in the design and attention to them at the design stage will prevent later trouble. Those points covered in greater detail in the earlier article on fluxes (*PE—June 13 '60, p 43*) are indicated by an asterisk.

(1) **Precleaning procedures*** are a must since a flux removes tarnish oxides but not surface dirt.

(2) **Flux to be used*** is best specified by chemical type following a selection process like that presented here for solders.

(3) **Flux application method*** is important because the presence of a flux in the right place and in the right amount is vital to reliability of the joint.

(4) **Solder alloy itself** should be specified by chemical composition, using the information and approach presented here. Product designations in Table II are given as examples for initial guidance to production.

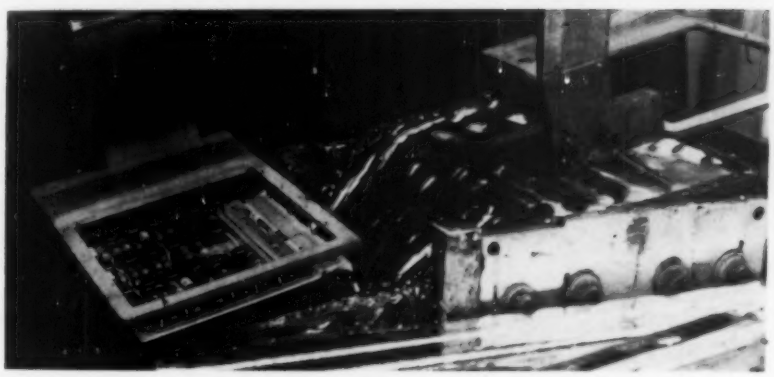
(5) **Pre-tinning*** is an optional step, particularly useful for difficult-to-solder metal. A strong flux will help a pre-tinning operation, but might not be suitable for final assembly. Pre-tinning can also be done by electroplating.

(6) **Solder method** specified depends on heat sensitivity of the assembly, quantity of joints, speed desired, cost, and other factors shown in the 7 basic methods above.

FOR DIFFERENT DESIGN PROBLEMS

5 . . INDUCTION SOLDERING, a variant of furnace soldering, permits localized heating. Only limitation: geometry of the assembly must permit soldering area to be completely surrounded by the induction coil. Another major advantage: fast heating rates are possible, controlled through electrical input to the coil. Hence the technique is adaptable to automatic assembly, though often used for manual soldering.

6 . . SOLDER DIPPING is specified when a number of points need soldering simultaneously—so that manual soldering would be time-consuming. As shown below, the assembly is held in a fixture and dipped briefly in a pot of molden solder. Two problems: continuous cooling of the pot surface; oxide film must be skimmed off before each dip.



7 . . CASCADE AND WAVE SOLDERING are dip methods that avoid problems of surface cooling and oxide films; they keep the solder fresh by continuous movement. In cascade soldering, shown above, solder is recirculated over a series of rolls, creating continuous wavelets. In wave soldering, a jet of solder is pumped into a pot of standing solder, creating a single, standing wave. In both methods the cool assembly is skimmed over the top of the wave, touching just long enough to wet the joint. This technique is easily made automatic.

III—INTERMETALLICS IN SOLDERED JOINTS

(table shows number of intermetallics that can form at soldering temperature between any two elements present. Example: Cu, soldered with an alloy containing Cd, can form 4 Cu-Cd intermetallics)

Metal		Solder-alloy Elements Sb	Bi	Cd	In	Pb	Ag	Sn
ALUMINUM	(Al)	1	0	0	0	0	2	0
ANTIMONY	(Sb)	0	0	2	1	0	2	1
BISMUTH	(Bi)	0	0	0	2	1	0	0
CADMIUM	(Cd)	2	0	0	0	0	3	0
COPPER	(Cu)	2	0	4	3	0	0	2
GOLD	(Au)	1	1	3	4	2	0	4
INDIUM	(In)	1	2	0	0	1	3	2
IRON	(Fe)	2	0	0	ND[1]	0	0	2
LEAD	(Pb)	0	1	0	1	0	0	0
NICKEL	(Ni)	5	2	LD[2]	5	0	0	3
PLATINUM	(Pt)	3	LD	LD	LD	3	3	5
SILVER	(Ag)	2	0	3	3	0	0	2
TIN	(Su)	1	0	0	2	0	2	0
ZINC	(Zn)	3	0	0	0	0	3	0

[1] No data; [2] Limited data

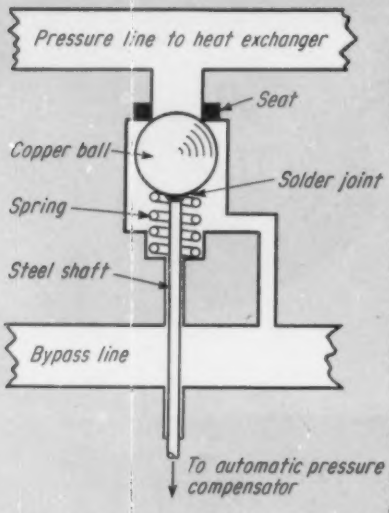
(7) **Limiting temperature-ranges** for base metal, tools, and solder must be specified because proper wetting depends on temperature. Table IV (next page) gives formulas for calculating these ranges. For heat-sensitive components, special notes must be added to the drawing to localize heat input.

(8) **Fixtures** should be requested for immobilizing the parts to be joined unless this feature is inherent in the assembly. With solders having a wide, pasty range, "cold" joints can easily result if movement occurs during cooling. The same problem arises with eutectic solders if cooling is slow.

(9) **Post-cleaning*** is essential to remove many corrosive flux residues. This is particularly important in electrical connections.

(10) **Inspection procedure*** is usually based on the con-

A WORKING EXAMPLE



PROBLEM: A relief valve in a hydraulic system (see sketch) incorporates a 0.333-in.-dia copper ball, soldered to a 0.0313-in.-dia steel shaft. Ball is seated by a spring compressed to 4 lb. Total weight of ball and solder is not to exceed 0.1 oz when assembly is immersed in silicone oil of specific gravity 1.1. Select a solder suitable for this joint, assuming a safety factor of 1.5, and a solder spacing of about 0.003 in.

SOLUTION: Compute the stress on the solder, assuming a butt joint.

S = Load × S.F./area = $4 \times 4 \times 1.5/\pi\ (0.313)^2 = 7800$ psi

Table II shows there are only four solders strong enough to meet this stress condition: Nos. 8, 13, 15, and 23.

Of these, No. 15 is the best choice: strongest and cheapest, and has good creep resistance. No. 15 has one disadvantage: a pasty range of 34° F, so a simple fixture should be specified to prevent movement between shaft and ball as the solder freezes.

The other three solders have disadvantages for this joint: No. 8, though a desirable eutectic, undergoes dimensional changes during freezing that might affect alignment and tolerances; No. 13 has borderline strength and high tin content, both offsetting low cost and narrow pasty ranges; No. 23 has acceptable strength, but high cost and a wide pasty range, plus a high tin content that might lead to intermetallics with copper (Table III) at the high soldering temperature required.

Weight of copper (vol = 0.02 cu in.; S.G. = 8.94) in oil is: $0.02\ (8.94 - 1.1) \times (16.39$ cc/cu in. $\times\ 0.0353$ oz/gm) = 0.091 oz

Weight of solder layer (assume 0.003 in. thick x 2 for extra solder in fillet) in oil is:

$\pi\ (0.313)^2\ (2 \times 0.003) \times (8.75 - 1.1) \times (16.39 \times 0.0353)/4 = 0.000{,}02$ oz (negligible)

Thus, total weight is 0.091 oz, less than the 0.1 oz stipulated.

Galvanic corrosion is not a problem in this application, since the joint is submerged in oil. If leakage of moisture into the system were a contingency, examination of Table I would show a substantial potential voltage between tin and steel, and enough between copper and steel to cause trouble. In this case, electroplating the soldered ball-shaft assembly with nickel would eliminate galvanic corrosion, while adding wear resistance to the ball.

tact angle and surface appearance. A major requirement: outlines of the joint should be clearly visible beneath the solder layer, so that the contact angle can be seen.

(11) **Protective coatings** may be necessary in corrosive environments. Many types of encapsulation and coating materials and processes are available (*PE*—Sep 19 '60, p 68).

IV—OPERATING TEMPERATURES FOR SEVEN SOLDERING METHODS

(S = solidus temperature; ΔS = increment above S for good soldering, normally 60 to 150 deg F depending on solder and assembly geometry)

Method (See picture previous page)	Operating Temperature, °F Tools	Work	Solder
1. Soldering iron 2. Torch soldering	S+(3 to 4) ΔS	S+(1.5 to 2) ΔS	S+ΔS
3. Resistance iron	None	S+(1.5 to 2) ΔS	S+ΔS
4. Furnace	S+ΔS	S+ΔS	S+ΔS
5. Induction coil	None	S+ΔS	S+ΔS
6. Solder pot 7. Solder wave or cascade	S+ΔS	S+(0.3 to 1) ΔS	S+ΔS

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EDITOR'S NOTE: For other recent articles on design for soldering or brazing, see the following:

Welding or Brazing Dissimilar Metals, Dec 19 '60, p 40—A requirement of no leakage at high pressure is a challenge to integral joints between two different metals. Article gives three ways to meet this requirement.

How to Choose the Right Solder Flux, June 13 '60, p 43—The old classifications of "corrosive" and "noncorrosive" fluxes are no longer adequate for today's soldering needs. This up-to-date flux selection guide is based on chemical origin, and covers all signficant types.

Designing Brazed Joints for 1000 F and Above, Aug 1 '60, p 40—High-temperature brazing efficiently joins stainless steels, alloy steels, and the superalloys. This survey tells how it works, when to specify it, how to select the right materials, and procedure for getting design started.

What the Tests Show About Soldered Aluminum Joints, Dec 7 '59, p 84—There are dozens of aluminum solders to choose from, each with its own characteristics. Here's how they're used, and how they will act after aging.

Methods of Soldering Aluminum, Mid-Sep '59, p 372—Reaction-flux soldering, friction soldering, and ultrasonic soldering are more applicable to aluminum than to other metals. These methods are discussed along with the properties of aluminum solders.

One Temperature for Successive Brazes, Dec 8 '58, p 84—Article shows how tighter production control along with special brazing alloys allows multiple brazing without reducing the operating temperature of final assembly.

—Ford R Park

when linkages need HARMONIC ANALYSIS

Feeding the working equation into a computer provided the handy table that accompanies this article. Now you'll find it easier to perform the harmonic analysis needed for efficient crank-and-rocker mechanisms.

DR FERDINAND FREUDENSTEIN, *chairman*
K MOHAN
Mechanical Engineering Dept
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The proportions of linkages can be determined readily enough by graphical methods. But when you have to know how these proportions affect the higher harmonics and inertia forces, complex analytical methods are very useful.

Equations for harmonic analysis of the general crank-and-rocker linkage were developed (by author Freudenstein) in *Journal of Applied Mechanics*, Dec '59, p 673. Those equations established procedures for the calculation of various coefficients and terms needed to determine whether a given mechanism has significant overtones.

But those equations still require considerable computations. Because crank-and-rocker mechanisms are important in the design of high-speed machinery, we carried the work a step further by programing on an IBM 650 computer the following:

Working equation for output angle:

$$\psi = K + \sum_{m=1}^{\infty} \frac{(-\tan\frac{1}{2}u)^m}{(-m)} \sin m\phi - \frac{C_0}{4} \sin u \cos\phi -$$

$$\sum_{m=1}^{\infty} \frac{\sin u}{4m} (C_{m-1} - C_{m+1}) \cos m$$

It was with this equation that we obtained the table that accompanies this article.

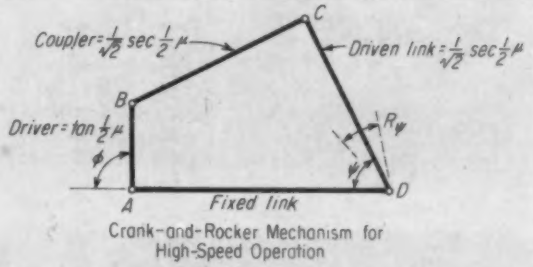
The rotation of rocker or output link (see diagram) has been expressed as a Fourier Series in terms of the input-crank rotation angle ϕ, and the proportions of the linkage are given in terms of a design parameter u. This parameter is the maximum value of the "pressure angle," which in the diagram is the absolute value of angle *BCD*

text continued, page 49

SYMBOLS

A_G	= acceleration of gyro
a_m	= amplitude of mth sine series term, radians
b_m	= amplitude of mth cos series term, radians
c_m	= amplitude of mth harmonic of rocker motion, radians
d_m	= amplitude ratio, mth to 1st harmonic of rocker motion
f_m	= amplitude ratio, mth to 1st harmonic of slider-crank motion
F_{max}	= maximum inertia force, lb
C	= variables defined by equations
K	= a constant in the Fourier Series
α	= variable defined by equations
u	= pressure angle, degrees
R_ψ	= maximum output rotation, degrees
ϕ	= input angle (drive crank)
ψ	= output angle (driven link)
r_p	= pitch radius of gear in example, in.

Subscripts, 1, 2, 3 . . . m refer to the order number of the harmonic; for example, mth harmonic; note that m is also used as a factor in the equations. Angular values, shown in radians, can be converted to degrees by multiplying by 57.3.



Crank-and-Rocker Mechanism for High-Speed Operation

REPRINTED—Circle 590, inside back cover

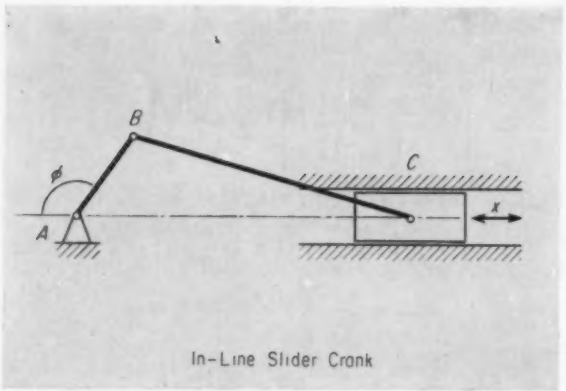
Harmonics of certain crank-and-rocker linkages

m	a_m	b_m	c_m	d_m	f_m
Case 1: u = 5, Rψ = 7.073315					
1	0.043660	−0.043641	0.061733	1.000000	0.000000
2	−0.000953	0.000000	0.000953	0.015437	0.015427
3	0.000028	−0.000014	0.000031	0.005022	0.000000
4	−0.000001	0.000000	0.000001	0.000012	0.000004
5	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....
Case 2: u = 10, Rψ = 14.160203					
1	0.087490	−0.087131	0.123479	1.000000	0.000000
2	−0.003827	0.000000	0.003827	0.030993	0.030944
3	0.000223	−0.000111	0.000249	0.002017	0.000000
4	−0.000015	.....	0.000015	0.000121	0.000030
5	0.000001	.....	0.000001	0.000008	.....
6	.....	.....	.....	.....	.....
Case 3: u = 15, Rψ = 21.274683					
1	0.131650	−0.130551	0.185405	1.000000	0.000000
2	−0.008666	0.000000	0.008666	0.046741	0.046531
3	0.000760	−0.000375	0.001000	0.005394	0.000000
4	−0.000075	0.000000	0.000075	0.000405	0.000101
5	0.000008	−0.000003	0.000008	0.000043	.....
6	−0.000001	0.000000	0.000001	0.000005	.....
Case 4: u = 20, Rψ = 28.431708					
1	0.176330	−0.173616	0.247458	1.000000	0.000000
2	−0.015546	0.000000	0.015546	0.062823	0.062318
3	0.001827	−0.000892	0.002000	0.008082	0.000000
4	−0.000242	0.000000	0.000242	0.000978	0.000242
5	0.000034	−0.000012	0.000036	0.000145	0.000000
6	−0.000005	0.000000	0.000005	0.000020	0.000002
Case 5: u = 25, Rψ = 35.647729					
1	0.221690	−0.216365	0.309774	1.000000	0.000000
2	−0.024573	0.000000	0.024573	0.079326	0.078367
3	0.003632	−0.001750	0.004000	0.012913	0.000000
4	−0.000604	0.000000	0.000604	0.001950	0.000479
5	0.000107	−0.000038	0.000114	0.000368	0.000000
6	−0.000020	0.000000	0.000020	0.000065	0.000005
Case 6: u = 30, Rψ = 42.941404					
1	0.267950	−0.258654	0.372423	1.000000	0.000000
2	−0.035898	0.000000	0.035898	0.096390	0.094741
3	0.006413	−0.003037	0.007071	0.018987	0.000000
4	−0.001289	0.000000	0.001289	0.003461	0.000843
5	0.000276	−0.000096	0.000292	0.000784	0.000000
6	−0.000062	0.000000	0.000062	0.000166	0.000013

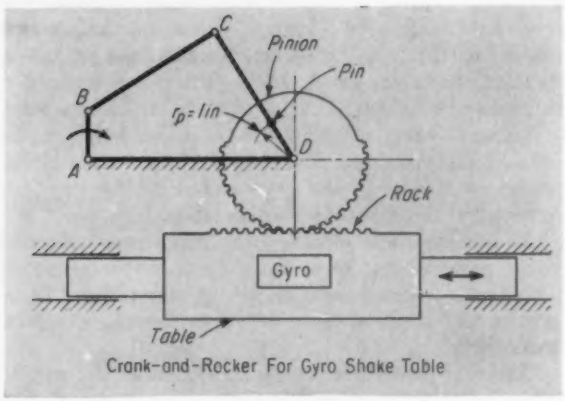
m	a_m	b_m	c_m	d_m	f_m
Case 7: u = 35, Rψ = 50.334529					
1	0.315300	−0.300351	0.435460	1.000000	0.000000
2	−0.049707	0.000000	0.049707	0.114153	0.111509
3	0.010448	−0.004843	0.011489	0.026384	0.000000
4	−0.002471	0.000000	0.002471	0.005674	0.001364
5	0.000623	−0.000210	0.000657	0.001509	0.000000
6	−0.000164	0.000000	0.000164	0.000377	0.000027
Case 8: u = 40, Rψ = 57.853304					
1	0.363970	−0.341265	0.498935	1.000000	0.000000
2	−0.066237	0.000000	0.066237	0.132757	0.128740
3	0.016072	−0.007244	0.017607	0.035289	0.000000
4	−0.004387	0.000000	0.004387	0.008793	0.002077
5	0.001277	−0.000408	0.001414	0.002834	0.000000
6	−0.000388	0.000000	0.000388	0.000778	0.000052
Case 9: u = 45, Rψ = 65.530207					
1	0.414210	−0.381196	0.562920	1.000000	0.000000
2	−0.085785	0.000000	0.085785	0.152392	0.146547
3	0.023689	−0.010303	0.025826	0.045879	0.000000
4	−0.007359	0.000000	0.007359	0.013073	0.003019
5	0.002439	−0.000724	0.002646	0.004700	0.000000
6	−0.000842	0.000000	0.000842	0.001496	0.000091
Case 10: u = 50, Rψ = 73.406779					
1	0.466310	−0.419839	0.627463	1.000000	0.000000
2	−0.108723	0.000000	0.108723	0.173274	0.164957
3	0.033799	−0.014039	0.036592	0.058318	0.000000
4	−0.011821	0.000000	0.011821	0.018839	0.004227
5	0.004410	−0.001190	0.004472	0.007127	0.000000
6	−0.001714	0.000000	0.001714	0.002732	0.000149
Case 11: u = 55, Rψ = 81.538039					
1	0.520570	−0.456870	0.692620	1.000000	0.000000
2	−0.135496	0.000000	0.135496	0.195628	0.184075
3	0.047024	−0.018417	0.050498	0.072908	0.000000
4	−0.018359	0.000000	0.018359	0.026507	0.005737
5	0.007646	−0.001824	0.007810	0.011277	0.000000
6	−0.003317	0.000000	0.003317	0.004789	0.000232
Case 12: u = 60, Rψ = 90.00000					
1	0.577350	−0.491515	0.758235	1.000000	0.000000
2	−0.166667	0.000000	0.166667	0.219810	0.204012
3	0.064150	−0.023280	0.068242	0.090001	0.000000
4	−0.027778	0.000000	0.027778	0.036635	0.007592
5	0.012830	−0.002619	0.013115	0.017890	0.000000
6	−0.006173	0.000000	0.006173	0.008141	0.000345

PROPORTIONS OF CRANK-AND-ROCKER LINKAGES

Case	u	AB/AD	BC/AD = CD/AD
1	5	0.04366	0.707836
2	10	0.08749	0.709887
3	15	0.13165	0.713282
4	20	0.17633	0.718091
5	25	0.22169	0.724385
6	30	0.26795	0.732164
7	35	0.31530	0.741499
8	40	0.36397	0.752602
9	45	0.41421	0.765473
10	50	0.46631	0.780324
11	55	0.52057	0.797297
12	60	0.57735	0.816604



In-Line Slider Crank



Crank-and-Rocker For Gyro Shake Table

minus 90°. The ideal pressure angle is zero, but in practice it is held to within a prescribed limit. Values of u from 5 to 60° in increments of 5 are given in the table with the corresponding values of R_ψ, the maximum output rotation in degrees.

The other terms in the working equation are defined by the following mathematical relationships, and they determine the various amplitudes and ratios shown in the table.

Equation for 1st harmonic

$\alpha = \sin u$; $\alpha_2 = \frac{1}{4}\alpha^2$; $\alpha_4 = 3/64\ \alpha^4$; $\alpha_6 = 5/512\ \alpha^6$; $\alpha_8 = 35/(128)^2\ \alpha^8$

$$C_8 = \alpha_8 \ldots$$
$$C_6 = \alpha_6 + 8C_8 \ldots$$
$$C_4 = \alpha_4 + 6C_6 - 20C_8 \ldots$$
$$C_2 = \alpha_2 + 4C_4 - 9C_6 + 16C_8 \ldots$$
$$C_o = 1 + C_2 - C_4 + C_6 - C_8 \ldots$$
$$C_m = (m \text{ odd}) = 0$$

The working equation for output angle can be expressed in the following forms:

$$\psi = K + \sum_{m=1}^{\infty} (a_m \sin m\phi + b_m \cos m\phi)$$

$$\psi = K + \sum_{m=1}^{\infty} c_m \sin (m\phi + \phi_m)$$

which give us the following:

$$\psi = K + c_1 \sum_{m=1}^{\infty} d_m \sin (m\phi + \phi_m)$$

where

$$a_m = (-\tan \tfrac{1}{2}u)^m/(-\mathrm{m})$$
$$b_1 = -\tfrac{1}{4} \sin u\ (2C_o - C_2)$$
$$b_m\ (m \text{ even}) = 0$$

$$b_m\ (m \text{ odd}) = \frac{-\sin u}{4m} = (C_{m-1} - C_{m+1})$$

$$c_m = \sqrt{a^2_m + b^2_m}; \cos \phi_m = a_m/c_m$$
$$d_m = c_m/c_1$$

In-line slider-crank mechanism

Equation above for the first harmonic can be compared with the corresponding equation in the harmonic analysis of an in-line slider-crank mechanism (diagram above) taken from *Engineering Dynamics—Vol IV—Internal Combustion Engines*, by C. B. Biezeno and R. Grammel, translated by M. P. White, Blackie and Son Ltd, London, p 6, Eq (5) and (6):

$$X = X_o + e_1 \sum_{m=1}^{\infty} f_m \sin m\phi$$

where X is the slider displacement and e_1 and f_m correspond to c_1 and d_m in the equation for the first harmonic.

The value of the link length ratio *AB/BC* for the in-line

HARMONIC ANALYSIS OF HIGH-SPEED MACHINERY

■ What is meant by "harmonic analysis"? It covers determination of resonant speeds, the severity of passing through various speed ranges (including resonant speed), and magnitude of the inertia forces. Such analysis will tell you how to design for efficient operation at high speeds and how to avoid undue resonance disturbances.

To determine these factors it is useful to express the motion in a Fourier Series—in other words, to express it in a series of harmonics of the form:

$$Y = K + a_1 \sin (\omega t + \phi_1) + a_2 \sin (2\ \omega t + \phi_2) + \cdots + a_m \sin (m\omega t + \phi_m) + \cdots$$

Here, Y represents the motion to be analyzed, K = a constant, a_m = amplitude of mth harmonic, ω = angular velocity, t = time—so that ωt represents ϕ, an angular displacement as a function of time. The term $a_1 \sin (\omega t + \phi_1)$ is the first harmonic or fundamental The other terms are the higher harmonics (like overtones in the musical field.

The harmonics of a given motion are used in the determination of the significance of resonant speeds and the corresponding inertia forces, which are proportional to the second derivative of Y. Higher harmonics are often neglected, as sometimes in connecting-rod motion of internal combustion engines. For complex motions as in crank-and-rocker mechanisms, the higher harmonics must be evaluated because the resulting amplitudes can be of greater significance. In these higher harmonics the associated critical speed is usually taken to be $m\omega t$, radians/sec. In some high-speed cam applications, harmonics as high as the 20th have been considered significant. ■

slider-crank should be identical to the link length ratio *AB/BC* for the crank-and-rocker. On this basis the tabular data include values for d_m and f_m which can be used to compare these ratios for the two types of mechanisms.

For small values of the maximum pressure angle *u*, the in-line slider-crank has practically the same value of harmonic amplitudes as the crank-and-rocker for even harmonics; but the slider-crank values are slightly lower.

As pressure angle increases, the slider-crank values become progressively lower than crank-and-rocker values. Thus, at a pressure angle of 30°, d_s and f_s differ by approximately 1.7%; while at 60° the difference is approximately 8%.

The ratio of 2nd to 1st harmonic amplitude, and 3rd to 1st harmonic amplitude can be significant in high-speed operation, as the following ratios show:

d_2 (30°) = 9.639% $\quad$ d_2 (60°) = 21.981%
d_3 (30°) = 1.90% $\quad$ d_3 (60°) = 9.0%

As a guide, it would seem reasonable to limit the maximum pressure angle to 30° or less in high-speed applications, and to 45° or less for moderate speeds; also 60° usually can be useful eventually only in low-speed and light-duty instrument drives.

The range R_ψ is approximately proportional to the pressure angle with the "constant" of proportionality varying between 1.41 and 1.50. The ratios d_m, c_m, amplitudes and the link length ratio *AB/AD* also appear to be approximately linear with the pressure angle—at least sufficiently so for qualitative estimates. Accurate values, however, can be calculated from the table.

Example

Analyze the harmonics of a shake table (sketch, p 49) for testing gyroscopes and other devices. The proportions of the crank-and-rocker are selected for high-speed operation with maximum pressure angle of 25°, the input crank rotates at 10 rps, and the gyro weighs 8 oz. Find:

(1) Proportions of the linkage;

(2) Inertia force of the gyro due to the 2nd harmonic, compared with the 1st harmonic;

(3) Amplitude of the first three harmonics of the table motion.

SOLUTION

(1) From the table, a 25° pressure angle corresponds to Case 5. The proportions are *AB/AD* = 0.22169; *BC/ADCD/AD* = 0.724385. If fixed link AD is 10 in., the driving crank AB is 2.217 in.; the coupler *BC* and the driven link CD are 7.244 in. each.

(2) The inertia force is equal to the mass of the gyro multiplied by its acceleration, and gyro acceleration is equal to pitch radius r_p of the gear multiplied by its angular acceleration. For the *m*th harmonic the gyro acceleration is

$$A_G = r_p \frac{d^2}{dt^2}\left[c_m \sin(m\phi + \phi_m)\right]$$

$$A_G = r_p m^2 c_m \left(\frac{d\phi}{dt}\right)^2 \sin(m\phi + \phi_m)$$

Therefore maximum inertia force F_{max} due to *m*th harmonic is:

$$F_{max} = \left[\frac{\text{gyro weight (lb)}}{g\left(\frac{\text{in}}{\text{sec}^2}\right)}\right] \times \left[r_p\, m^2\, c_m \left(\frac{d\phi}{dt}\right)^2\right] \text{lb.}$$

If g = 386 in./sec², gyro weight = 0.5 lb, r_p = 1 in.,

$$\left(\frac{d\phi}{dt}\right) = 10 \times 2\pi \frac{\text{rad}}{\text{sec.}}$$

$$F_{max} = \frac{0.5}{386} \times 1 \times (20\pi)^2 \times m^2\, c_m$$

Taking *m* and c_m from the table gives:

1st harmonic m = 1; c_m = 0.309774; F_{max} = 1.587 lb.
2nd harmonic m = 2; c_m = 0.024573; F_{max} = 0.503 lb

$$\text{Ratio 2nd to 1st harmonic} = \frac{0.503}{1.587} \times 100 = 31.7\%$$

(3) From the table for Case 5, the amplitudes of the first harmonics are given in the c_m column as:

c_1 = 0.309774; c_2 = 0.023573; c_3 = 0.00400 radians

Ratio of higher harmonics to the 1st harmonic can also be obtained from the d_m column. For example,

Ratio of amplitude of 2nd to 1st: (d_2) = 0.079326 = 7.9%

Ratio of amplitude of 3rd to 1st: (d_3) = 0.012913 = 1.3%

The significance of these values depends upon the particular design requirements, as well as the number of decimal places you want to use.

ACKNOWLEDGEMENTS: *The authors are indebted to the Electronic Research Laboratories of Columbia University for having made available their computational facilities and to Mr. Sy Newman for programing help on the IBM 650 computer.*

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EDITOR'S NOTE: For more information on designing four-bar linkage mechanisms see:

Special Chart Leads You to Four-bar Linkage Proportions, Sep 19 '60, p 76—With two points given, this handy chart quickly locates the other two. You find the proportions of all four bars without cumbersome mathematics or graphical methods.

5 Graphical Methods for Designing Four-bar Linkages, Apr 4 '60, p 37—Roundup of methods for synthesizing four-bar linkages, including the point position reduction method developed by Kurt Hain.

Robert's Law Helps You Find Alternate Four-bar Linkages, Oct 27 '58, p 54—Method of similar triangles is explained and expanded by author's method of laying off the link lengths along a straight line.

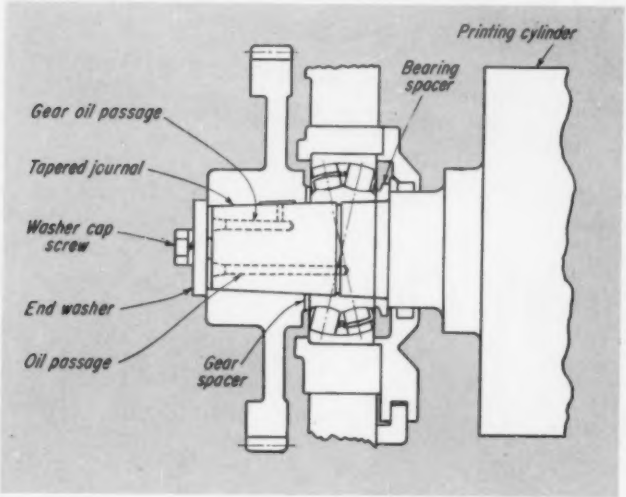
Linkage Design Techniques, Dec '54, p 133—Comparison of 4 methods—two approximate and two exact—for construction and design of four-bar linkages.

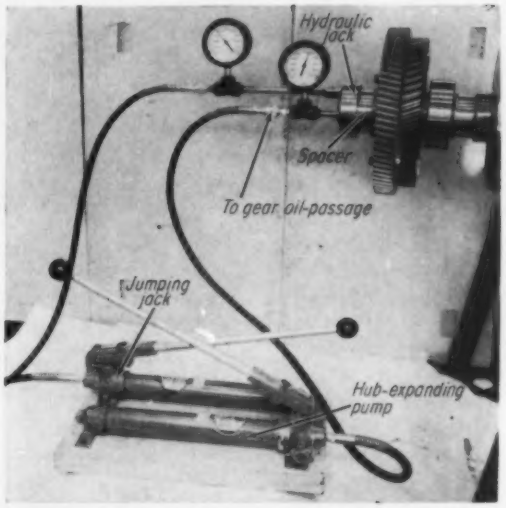
Linkage Layouts by Mathematical Analysis, Aug '55, p 165—Shows how to obtain a specified relationship between input and output for a differential by determining number and types of links needed.

Frederick Marich

Gear Mounted on Shaft Hydraulically

Non-damaging interference fit is handled by two pumps—
oil from one stretches gear hub, oil from other jacks it into place.
When hub contracts, gear is locked in nonslip fit.



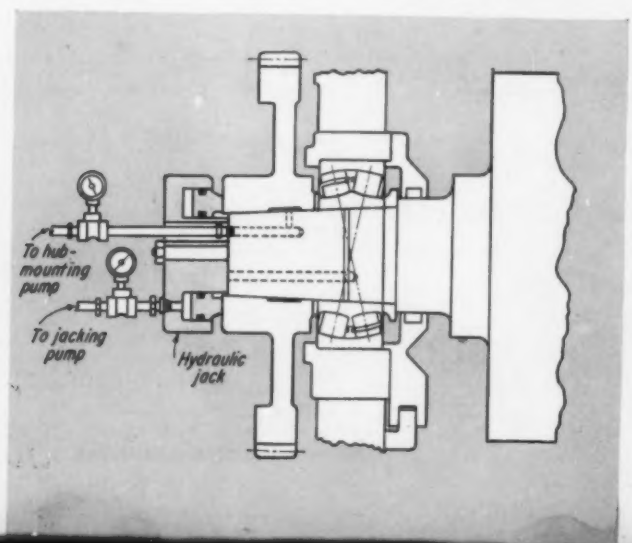


TWO HYDRAULIC PUMPS and a hydraulic jack mount the gear (or bearing). One pump forces oil through passages drilled in the tapered shaft. This oil expands the gear hub. Second pump operates the hydraulic jack, which forces gear into position on shaft. Eliminating key and keyway results in hub of uniform cross-section and avoids localized distortion.

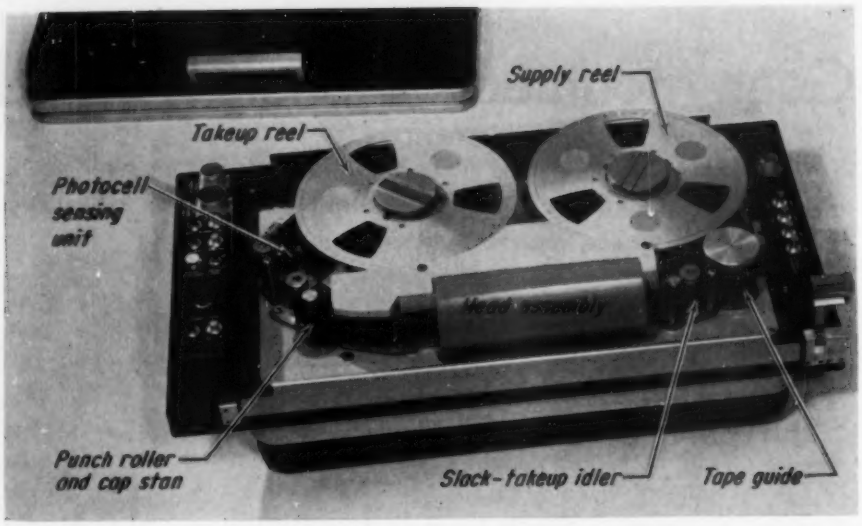
First the gear is positioned by hand on the lubricated shaft. The hydraulic jack and spacing collars are installed and retained by cap screws threaded in the end-washer holes. A clearance hole in the jack permits oil to be pumped through the oil passages leading to the gear hub.

Pump for the hydraulic jack is operated until pressure reaches 1000 psi. Then oil is pumped to the gear hub until the hydraulic-jack gage shows a pressure drop, indicating that the gear has expanded and started to move up the shaft. The two pumps are operated simultaneously until the spacer behind the gear is tight. This requires pressure of about 7000 psi in the hub-expander, and about 8000 psi in the jack circuit. The hub-expanding pressure is relieved first, and the gear seats firmly on the shaft.

When the gear has to be removed, a safety washer is installed with about ⅛-in. clearance from the end of the gear, to hold it in place after it has been loosened. A hole in the washer permits the connection of a hydraulic pump to the oil passage in the gear. At about 8000 psi the gear loses its grip and slides free. The safety washer is removed and the gear taken off the shaft.

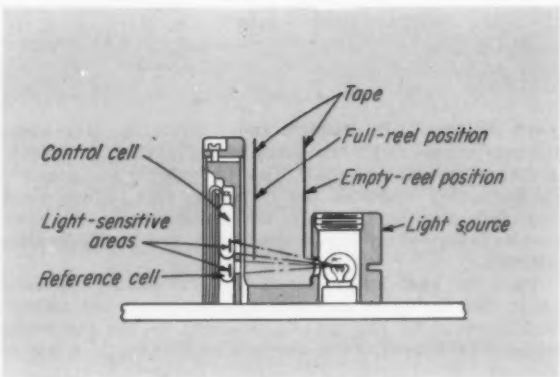


PS . . . Keyless hub-fitting system mounts bearings and gears on tapered shafts from 3 to 10 in. dia in printing presses and paper folders. No hub slippage occurs despite frequency emergency stops which halt a press running at 500 rpm in less than 30 revolutions of the print cylinder. The system provides improved accuracy in mounting gears, also reduces cost by eliminating cutting and fitting of keyways. Only hand tools are needed for removing gears or bearings. Patented system is used on printing presses produced by R Hoe & Co, NYC.



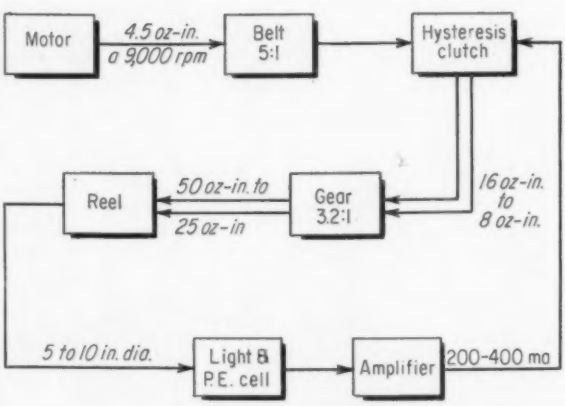
Photocell Adjusts Magnetic Clutch

Tape in this recorder is kept under constant tension by light-sensitive unit—it matches the torque driving the supply and takeup reels to the amount of tape on each.



PHOTOCELL CONTROLS sense the amount of tape on supply and takeup reels, and adjust coupling force in drive clutches accordingly. To maintain constant tape tension, the torque driving each reel must vary directly with the diameter of the tape-pack. Normal tape tension is 10 oz. Tape-pack diameter varies from 5 to 10 in., so the required torque varies from 25 to 50 oz-in. at each reel.

The sensing units, one per reel, each contain two photocells. As a reel fills up, the section of tape passing the sensing unit moves closer to the photocells, reducing the amount of light striking the upper (control) cell. The lower (reference) cell remains exposed at all times, correcting for any variations in light-source intensity. The degree of shading and, therefore output voltage of the control photocell, depends on amount of tape on the reel. This output voltage is amplified and applied to the hysteresis clutch which then supplies the necessary coupling force.

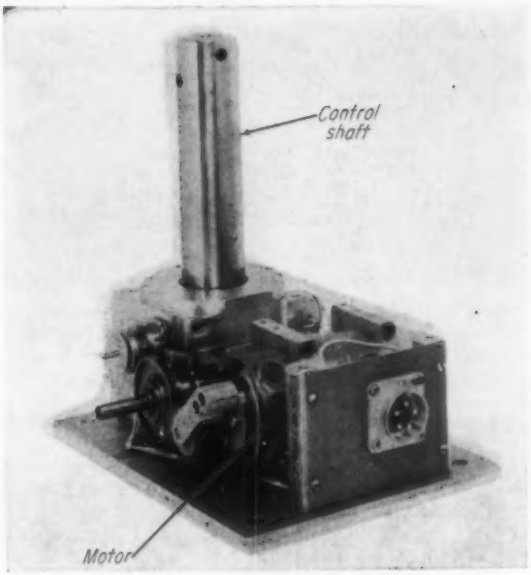


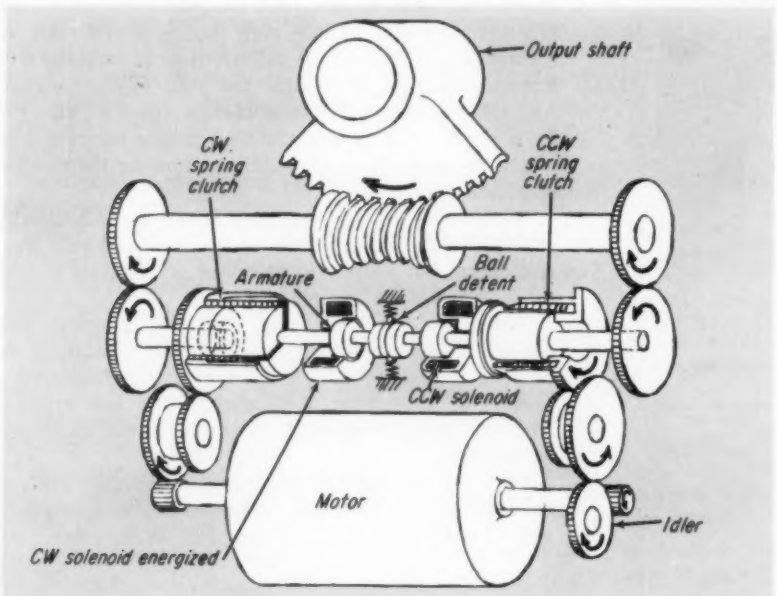
PS . . . Wide-band system records one channel of 4-megacycle information for one hour at 12.5 ips or two channels for ½ hr at 25 ips. Tape-reel drives use a 1/25-hp, 9000-rpm, 400-cps induction motor. Clutch, a stationary-coil model rated at 18 oz-in., reduces work required of the drive capstan. The AR-300 airborne recording system is produced by Ampex Corp, Redwood City, Calif.

Dual Clutches Speed Response of Missile Controls

Drive motor runs continuously; one end or the other is engaged to supply the desired motion. The all-mechanical unit eliminates periodic leakage checks required with hydraulics.

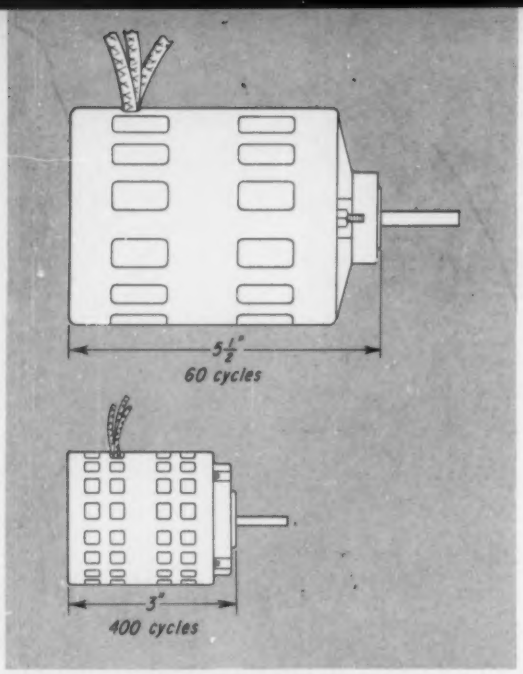
ACTUATOR responds fast enough to allow using any of three types of missile-command signals: continuous, pulsed, or dither type. A continuous signal keeps the actuator moving in the desired direction without interruption, throughout the desired magnitude of rotation. A pulsed signal moves the actuator output in short increments until the desired magnitude is achieved. A dither signal cycles the output a small increment in the desired direction and then moves it a smaller increment in the opposite direction and recycles. Net movement is then in the desired direction; these pulses are repeated until the desired position is achieved.





DRIVE MOTOR rotates continuously, so response is fast enough for control applications. Solenoid-operated clutches respond to signals and connect output to the end of motor that will give the desired direction of movement. An idler in one of the gear trains reverses direction of drive to one clutch. Solenoid armatures are mechanically interconnected, so only one clutch can be engaged at a time. When both clutches are deenergized, spring-loaded ball detent centers solenoids, and locks the non-reversible worm-and-gear segment.

PS . . . Electromechanical actuator is designed for the Bumblebee missile project, a joint effort of the Applied Physics Lab of Johns Hopkins Univ and Convair. The unit has a response time of 8 millisec from start of command signal to full torque. Frequency response ranges up to 50 cps of full clockwise rotation and full counterclockwise rotation back to recycling position. Average output torque of the actuator is 1000 lb-in. at 200°/sec with an input of 49 v dc and 12 amps. Miniaturized package is shaped to fit within a 90° section of an annulus of 7.5 in. ID and 8 in. long. Model 0116 electromechanical actuator is produced by American Electronics Inc, Fullerton, Calif.

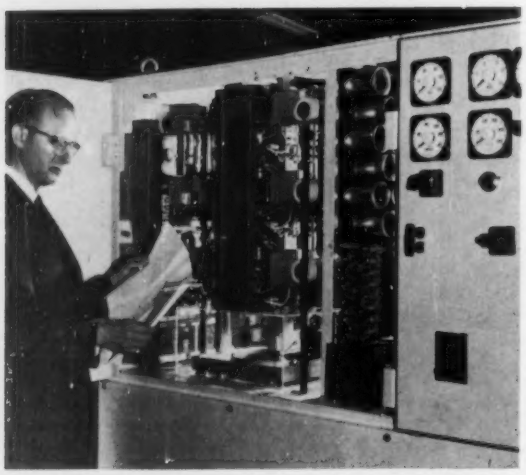


TWO 1/50-HP MOTORS. The large one rotates at 1725 rpm, weighs 4.5 lb. Small one rotates at 7200 rpm, weighs 1.6 lb.

HOW PRACTICAL Is 400-CYCLE POWER —TODAY?

It's still expensive. But it does many jobs better than the standard 60-cycle variety. And compact static frequency-converters—changing 60-cycle to 400—will soon be cheap enough to handle many jobs, old as well as new.

FRANK E HALL, *assistant editor*



LABORATORY MODEL 50-kva static inverter by General Electric Co. Portable unit changes dc to variable frequency ac—from 50 to 500 cycles. It can be used to supply power to a battery of routers or internal grinders.

If you had 400-cycle power available, you could design a vacuum cleaner that was much smaller, lighter, and more efficient . . . or an inexpensive router or internal grinder that would rotate with direct drive at speeds up to 24,000 rpm. Until now, such new products have been impractical because there was no inexpensive component, compact enough to go right into the equipment, that would convert 60 cycles to 400. But solid-state elements make this new approach possible, even though several years off. Electronic suppliers for the military now have off-the-shelf frequency-changers that show the ideal can be reached. And GE has built a 50-kva solid-state inverter (*PE—Feb 20, p 8*); this is more powerful than needed for most manufacturing applications, but indicates how far the development has proceeded.

Within the next few years 400-cycle static frequency-changers of high power will be practical—not only small and cheap, but shaped to fit. Now is the time to start thinking about designing with them.

Distribution of alternating current has always been plagued by voltage drop, and with 400-cycle current, the problem is multiplied in proportion to the frequency or roughly 6⅔ times that of 60 cycles. The new approach circumvents this problem by converting to 400 cycles right on the spot.

Once the practical 400-cycle power supplies are available, the high cost of 400-cycle motors and other components will be reduced as demand increases. With volume pro-

MODULAR FREQUENCY-CHANGER. Top section plugs into bottom section. Bottom section is ac-to-dc power supply; takes 115 v ac, 60 cps, and puts out 28 v dc, 5 amps. Top is an inverter which changes 28 v dc to 115 v ac 400-cps square wave, unregulated 100 va. Combined, the two units comprise frequency changer, measuring 5⅝ x 5⅞ x 7⅝ in., which converts 60-cycle 115 v to 400-cycle 115 v ac, 100 va. Victory Electronics Inc, Westbury, NY.

duction, prices should approach those of 60-cycle components, although some units such as circuit breakers may remain more expensive.

Where 400-cycle is now

This is not all supposition. There is a push right now for cheaper 400-cycle components. Aside from the military applications, large machine tools and computers are two areas where 400-cycle power is catching on because it enables using small, lightweight motors.

Other industrial applications include routers, high-speed internal grinders, borers, portable tools, welding (especially where wave shape is important), fluorescent lighting. Except for the computers, use of 400 cycles in these other areas does not usually justify the higher costs.

In the future, applications could include machine-control circuits, business machines, household appliances such as vacuum cleaners, fans, and the hobbyist's hand tools.

Ray Maul of GE's General Engineering Laboratory, Schenectady, says: "Don't overlook the new unconventional power sources coming along—solar cells, thermionics, thermoelectric, etc. Their output is dc, so as long as you must invert to ac, why not invert to 400 cycles wherever you can use the advantages of this frequency?"

For the most part, today's applications use motor-generator sets as their source of power. Motor-generators are reliable and the inertia of their rotating shafts offers some protection against line transients. The output voltage can be used directly by 400-cycle components without modification. M-g sets are available off-the-shelf in practically any power rating you require—volt-amperes to kilovolt-amperes. However, motor-generators are expensive (although still less costly than static frequency-changers) and are relatively bulky and noisy, need a periodic maintenance, and can't approach the compact size promised by the solid-state devices. In other words, they are practical *today* in 400-cycle applications where the extra cost and bulk are justified.

Solid-state devices today, according to Earnest Levy, engineering-section manager, of Sorenson & Co., South Norwalk, Conn, are in the "model-T" stage; circuits are complex; they must be refined; safety circuits must be designed. He thinks it will be about 5 years before solid-state devices overtake motor generators.

Ledyard Kastner, v-p of Victory Electronics Inc, Westbury, NY concedes this is true for higher-power units, but adds, "It's true we have a long way to go, but right now we supply modular, off-the-shelf static frequency-changers with a power output greater than 100 va without need of an external heat sink or blower. We are not far from the power requirements of industry, but we have our work cut out for us to get down to your ideal size and cost."

Along with limited power and lack of historical evidence of reliability, present-day static frequency-changers have an added disadvantage when used with motors such as hysteresis types that need sine wave to operate. The output of the static converter is square wave which must be filtered to get a sine wave. Filters induce some heat and add 5 to 50% to the weight of the converter.

Voltage regulation is important in any system—rotating or static—where power supply is finite: increase of load can cause serious voltage drop. When you use 60 cycles, you get it direct from the power company whose source is infinite relative to your machine.

Indications are that these liabilities will be overcome. In fact, in low-power applications (below 100 va) solid-state frequency-changers are successfully challenging motor generators.

These frequency-changers use either SCR's (silicon controlled rectifiers) or power transistors as switching elements. Generally, the unit is a combination rectifier and inverter. The rectifier changes the 60-cycle ac to dc and the inverter changes the dc to 400-cycle ac, or whatever other frequency you desire within its capabilities.

Other means of conversion

Vacuum-tube inverters (such as thyratrons), vibrators, static frequency-multipliers, and motor generators or alternators, are all sources of 400-cycle power. Some, such as the thyratron and the vibrator, require dc as their input; the multipliers and motor generators can operate from 60-cycle ac. An article is in preparation comparing the unique characteristics of each of these types, as well as the static frequency-converter.

Other frequencies

John A. Zimmerman, of Robbins & Myers Inc, Springfield, Ohio, says: "Although 400 cycles is the most common high frequency because of military standardization, industrial applications involve quite a variety of other frequencies. For high-speed internal grinding it is desirable to maintain a high peripheral speed when grinding small-diameter bores. High frequency is a must for obtaining speeds of 100,000 rpm. Frequencies range from 500 to 3300 cycles.

"There are many applications where a change of speed is desirable but where the dc or other variable-speed motor is either too large or expensive. In such cases we supply variable-frequency alternators (pneumatic, hydraulic, electric, or manually operated) which are matched to the speed of the motor." ■

WHY 400 CYCLES?

The story goes that both the Navy and Air Force were interested in higher frequencies. Air Force wanted the highest practical multiple of 60—420 cycles—so the electric motors used in aircraft could be smaller and lighter. Navy wanted smaller and lighter components, too, but in addition has problems of distribution because of the size of its ships, so Navy held out for 360 cycles. When the impasse was reached, instead of flipping a coin to settle on one or the other, the two services compromised—at 400, which, not being a multiple of 60, added a few new problems.

NOMENCLATURE

Rectification	—changing ac to dc
Inversion	—changing dc to ac
Conversion	—changing ac to ac (one frequency to another)
Dc transformation	—changing dc to dc (one voltage level to another)

The ACCELERATION of SCIENCE

— crisis in our technological civilization

For 300 years science has grown exponentially, and the trend is continuing. Manpower can't possibly keep pace; soon there will be far more breakthroughs than we can ever handle. A national science policy is one possible answer, but it would need specialists in the long view. Scientists themselves are too close to trees to see their way out of the forest.

DEREK J de SOLLA PRICE, *professor of the history of science*
Dept of the History of Science and Medicine, Yale University

The basic problems currently afflicting the structure and organization of science concern what one might well call the "size of science"—the magnitude of the effort in terms of numbers of men working, papers written, discoveries made, financial outlay involved.

For a preliminary exercise in the arithmetic of science, let us first examine the history of the vital process that made science assume a strongly cumulative character. The origin of this was in the 17th-century invention of the scientific journal and the device of the learned paper—one of the most distinct and fundamental innovations of the Scientific Revolution. The earliest surviving journal is the *Philosophical Transactions* of the Royal Society of London, first published in 1665. It was followed rapidly by some three or four similar journals published by other national academies in Europe. Thereafter, as the need increased, so did the number of journals, reaching a total of about 100 by the beginning of the 19th century, 1000 by the mid-century, and some 10,000 by 1900. According to the *World List of Scientific Periodicals*—a tome larger than any family Bible—we are now well on the way to the next milestone of 100,000 such journals.

Now this provides a set of heads that are reasonably easy to count. If we make such a count extending in time-range from 1665 to the present, it is immediately obvious that the enormous increase in the population of scientific periodicals has proceeded from unity to the order of 100,000 with an extraordinary regularity seldom seen in any man-made or natural statistics. To a high order of accuracy, the number has increased by a factor of 10 during every half-century, starting from a state in 1750 when there were about 10 scientific journals in the world. From 1665 to 1750, the birth span of the first 10 journals, the regularity is not quite so good, but this indeed is exactly what one might expect for a population that was then not large enough to treat statistically. No sort of head-counting can settle down to mathematical regularity until the first dozen or so instances have been recorded.

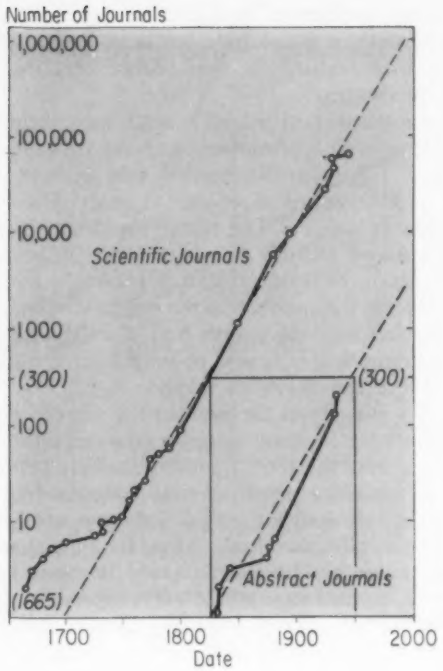
The detail at the beginning of the curve of growth is rather revealing in terms of its historical implications. The growth acts as if it had started from a first journal at a date nearer to 1700 than 1665. Thus, the curve indicates that, in some sense, the scientific journal was born a little too soon. The first publications were demonstrably precursors rather than true originators of the process. This is particularly interesting when one considers the difficult periods which the Royal Society and the other academies experienced once the initial flush of enthusiasm had passed. They went through grave crises and had to suffer rebirth early in the 18th century.

Abstract journals are born

In the course of this proliferation of the scientific journals, it became evident by about 1830 that no scientist could read all the journals or keep sufficiently conversant with all published work that might be relevant to his interest. With some 300 journals being published, some radically new effort was needed. Yet again there was an invention as deliberate and as controversial as the journal itself: the abstract journal.

Now a single journal could never suffice, and in accordance with the convenient compartmentalization of science current by this time, further abstract journals were created to fill the needs of the various specialist groups. Because it presented a solution to the crisis, the abstract journal removed the pressure, and the number of plain journals was enabled to grow unhampered. This growth has continued to the present day. Because of this proliferation, however, the number of abstract journals has also increased, following precisely the same law, multiplying by a factor of 10 in every half-century. Thus, by about 1950 we reached the point at which the size of the population of abstract journals had attained the critical magnitude of about 300. This is, of course, the reason why during the last decade scientists have been concerned about the need for abstracts of abstracts, calling this an "information problem," which seems to require some process of electronic sorting of abstracts as a means of coping with the rising flood of literature.

EDITOR'S NOTE
This article has been abstracted from a chapter in the author's book *Science Since Babylon*, to be published by the Yale University Press this month—Richard M Koff



It is interesting to reflect that, on the basis of this historical evidence, one can show that any new process would bear the same relation to abstracts as the abstracts have to original papers. This relation involves a compression by a factor of about 300—the number of journals that seem to have necessitated the coming into being of each abstract journal. Now it seems that the advantage at present providable by electronic sorting may be of a considerably smaller order of magnitude—perhaps a factor of the order of 10. If this is so, it follows that the new method must be no more than a palliative and not the radical solution that the situation demands. It can only delay the fateful crisis by a few paltry decades.

Number of papers is exponential too

The law of exponential increase found for the number of scientific journals is also obeyed for the actual numbers of scientific papers in those journals. In fact, it seems an even more secure basis to count the heads of whichever papers are listed by one of the great abstract journals or bibliographies than to take a librarian's list of the journals themselves. A list of papers is likely to be a little more comprehensive and more selective than any list of journals which may, from time to time, publish scientific papers immersed in nonscientific material. As a good specimen of the result of such a statistical investigation of numbers of scientific papers, there is next presented a curve showing the numbers of papers recorded by *Physics Abstracts*. From 1918 to the present the total number of physics papers recorded in the abstracts has followed an exponential growth curve to an order of accuracy which does not fluctuate by more than about 1% of the total. There are now about 180,000 physics papers recorded in these volumes, and the number has steadily doubled at a rate even faster than once every 15 years. In this curve, one particular side-effect is worth noting. The data show that during World War II, in the period 1938-48, the production of physics papers was reduced to reach a minimum of very nearly one-third what it normally would be.

However, once science had recovered from the war, the curve settled down to exactly the same slope and rate of progress that it had before. It had neither a greater nor a less initial slope; it is exactly as if the war loss had not occurred. The present curve runs accurately parallel to its projected prewar course.

Science is our fastest growing product

It must be recognized that the growth of science is something very much more active, much vaster in its problems, than any other sort of growth happening in the world today. For one thing, it has been going on for a longer time and more steadily than most other things. More important, it is growing much more rapidly than anything else. All other things in population, economics, nonscientific culture, are growing so as to double in roughly every human generation of say 30 to 50 years. Science in America is growing so as to double in only 10 years—it multiplies by eight in each successive doubling of all nonscientific things in our civilization.

The past three centuries have brought science from a one-in-a-million activity to a point at which the expenditure of several percent of all our national productivity and available manpower is entailed by the general fields of science and its closely associated applications.

An international science handicap race

It is instructive in this study to compare the growth charts of Europe with those for the United States. All the available statistics show that the United States has undergone the same sort of accurately exponential proliferation as Europe. The difference is, however, that once the United States started, it made its progress by doubling in scientific size every 10 years rather than every 15. The explanation of the rate difference is difficult, but the fact seems quite clear. Once the United States had, so to speak, decided to get down to a serious attempt at scientific education, research, and utilization, it was able to carry through this process at a rate of interest considerably higher than that in Europe.

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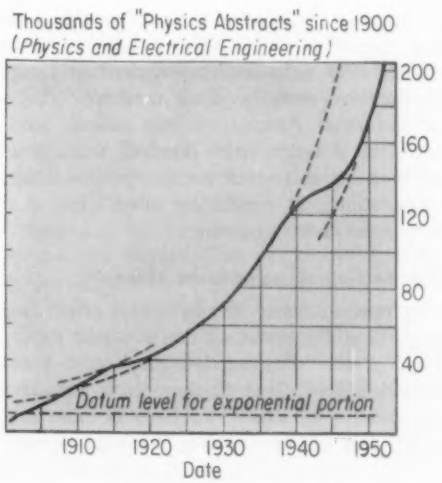


A great part of the explanation is probably due not to any special and peculiar properties of the American way of life as compared with the European but merely to the fact that this country was expanding into a scientific vacuum. Furthermore, it was doing it with the help of that high state of science already reached and held as a common stock of knowledge of mankind at the date when the United States started its process. Europe had to start from the beginning, and by the 18th or 19th century it had a considerable accretion of tradition and established institutions of science and technology.

Whatever the reason, the United States continued to expand at this rate faster than Europe, and eventually it acquired an intensity of science in society that became greater than that of Europe. One can consider the scientific advancement of Russia in exactly the same way. In Czarist Russia, science was not altogether inconsiderable —it partook of the general level of Europe—but after 1918 a determined effort was made to expand science. Again the statistics show that the advance has been very accurately exponential, and that the doubling time is of the order of some seven years rather than the 10 of the United States and the 15 of Europe. Again, one can attribute this in large part not to any particular exellence of the Russians or to a degree of crash-programing but rather to the fact that if they wanted to do the job at all, there was only one way of doing it; and this involved being able to start from a world-state of scientific knowledge that was considerably higher for them than for the start of the United States.

Lastly, we may take the case of China. Here we have an even more recent start and, consistent with the theory, we see that the statistics in that country indicate a doubling every five years. Again, rather than attribute any particular high quality to the Chinese, I would suggest that they are simply expanding into a larger scientific vacuum, starting at a higher level than any of the earlier protagonists.

The whole thing is like a gigantic handicap race in which the country that starts last must necessarily have the highest initial speed, and it seems fairly conclusive that this speed can readily be maintained—it certainly has been by America—so that the state of science must eventually reach the concentration that we see in the most highly developed countries. It is reasonable to suppose from the very universality of science and from its supra-national qualities that it is much more likely for the world to reach a state of uniform development and exploitation in this direction than in many another. The handicap race of Industrial Revolutions has indeed been so well designed that it seems likely that all runners will come abreast, reaching a size of science proportional to their total populations, at much the same time, a time not too many decades in the future.

And the decline of science to come

Having now discussed the historical origins and statistical progress of the device of the scientific paper and the profession of the scientist, we must next consider the decline and fall of these things. It is indeed apparent that the process to which we have become accustomed during the past few centuries is not a permanent feature of our world. A process of growth so much more vigorous than any population explosion or economic inflation cannot continue indefinitely but must lead to an intrinsically larger catastrophe than either of these patently apparent dangers.

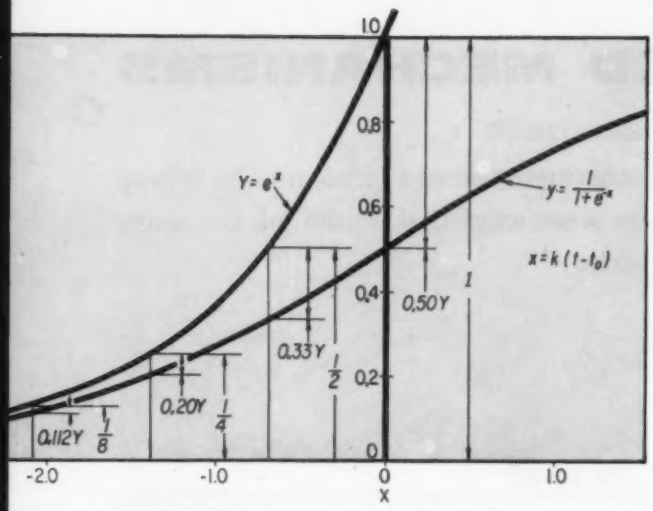
The mathematical theory is again most helpful if we demand only an approximate picture and require no maze of detail. Exponential growths that become saturated and thereby slowed down to a steady level are very common in nature. The rabbit population in Australia or the colony of fruit flies in a bottle all grow rapidly until some natural upper limit is reached. In nearly all known cases, the approach to the ceiling is rather strikingly symmetrical with the growth from the datum line. The curve of growth is a sigmoid or logistic curve, S-shape, and even above and below its middle.

It is a property of the symmetrical sigmoid curve that its transition from small values to saturated ones is accomplished during the central portion (halfway between floor and ceiling) in a period of time corresponding to only the middle six doubling periods independent of the exact size of the ceiling involved. Thus, the time at which the logistic curve has fallen only a few per cent below the expected, normal exponential curve represents the onset of the process. Three doubling periods later, the deficiency is 50%, the sigmoid curve reaching only half the expected height. Thereafter, the sigmoid curve becomes almost flat, while the exponential curve continues its wild increase.

For science in the United States, the accurate growth figures show that only about 30 years must elapse between the period when some few percent of difficulty is felt, and the time when that trouble has become so acute that it cannot possibly be satisfied. It seems quite apparent from the way in which we have talked, from time to time in recent years, about manpower difficulties in science that we are currently in a period in which the onset of a manpower shortage is beginning to be felt. We are already, roughly speaking, about halfway up the manpower ceiling.

Some of the effects of living in a state of saturated science are already apparent. If the cumulative expansion of science rapidly outpaces all efforts we can make to feed it with manpower, it means that more and more things will arise naturally in the life of science and require attention that cannot be given. There will be too many discoveries chasing too few workers. At the highest level we must come to a situation at which there are too many breakthroughs per square head. In all previous times, for each breakthrough, such as that of X-rays in 1895 there were many large groups of physicists who could attack the new problem and start to work on it. Already in our own times we have a decrease of this. In any particular area of breakthrough there are initially fewer capable specialists, and many of these are faced with the prospect of having too many interesting tidbits on their own plate to feel the need to go elsewhere, however exciting that might seem.

Thus far nothing has been said about the quality of research as opposed to its quantity or its cost. One may, for example, study the growth of only important discoveries, inventions, and scientific laws, rather than all such things, important and trivial; any count of this sort immediately shows that the growth, though still



SIGMOID CURVE, in which $y=(1+e^{-x})^{-1}$, runs close behind exponential ($Y=e^x$) for most of its early life. When a difference begins to show and sigmoid lags exponential by 11.2% the end is in sight. In three doubling periods of the exponential the sigmoid curve is halfway to its saturation level and lagging the exponential by 50%.

exponential, possesses a doubling time that is much longer than that of the gross growth of science. The actual stature of science, in terms of its achievements, appears to double within about one generation (some 30 years) rather than in the 10 years that doubles numbers of papers and numbers of scientists.

The cost of science is higher still

What is particularly impressive is that the cost of science, in terms of expenditure in money and national income, grows much faster than the gross size. Indeed, it has been suggested that United States research and development costs double every six years, whereas the persons listed in American Men of Science double only in 12 years. Thus it would seem that the cost goes up as the square of the number of men working, and the number of men increases as the square or cube of their effectiveness in increasing the stature of science. We have therefore a fourth or sixth power law of rapidly diminishing returns. To proceed with rocketry at 10 times the present effectiveness would cost say ten thousand or perhaps a million times as much money!

What this means to technology

Science in an age of saturation must begin to look rather different from its accustomed state. I believe it is without question that the occurrence of such a change must produce effects at least as disturbing to our way of life an an economic depression. For one thing, any slackening of the research pace of pure science must be reflected quite rapidly in our advancing technology, and thereby in our economic state. Clearly there is no direct, one-to-one relationship of pure science to technology. Even if there were declared a sudden moratorium on pure scientific research, or (what is more plausible) an embargo on growth that allowed all such work to continue but without the habitual 6% yearly increase in manpower, there would still be enough of a corpus of knowledge to provide for technological applications for several generations to come. As Robert Oppenheimer has expressed it, "We need new knowledge like we need a hole in the head."

There is, however, a snag in the argument as expressed above, for in the past the expansion of science and of technology have proceeded hand in hand. I suspect, because of this intimate relationship, that although technology might be left with a great bulk of pure science waiting to be applied, any decrease in the acceleration of science will prove an unaccustomed barrier to industry, and that the flow of new ideas into industry will in some indeterminate way suffer and drop spectacularly. We are now geared to an improvement of technolgoy at a rate of some 6 to 7% per annum, and a decline in this must affect all our lives. Then, again, if manpower is chronically to be in short supply in the world of science, it will follow that *what* we do is much more important than *how much* we do it.

In this new state, our civilization will rise or fall according to the tactics and strategy or our application of our scientific efforts. It is anarchical to decide such issues by letting ourselves be ruled by the loudest voices. It may or may not be worthwhile to support missile research to the hilt, but no man can make such a decision without considering the possibility that this work will ruin the chances of half a dozen other fields for an entire generation. In a condition in which so much of our scientific research is supported by military contract and federal projects, it seems no man's business to consider the possible damage which could come in our new saturated state.

If the supply of research cannot simply be allowed to follow the ephemeral demand, it seems also that we can no longer take the word of the scientists on the job. Their evaluation of the importance of their own research must also be unreliable, for they must support their own needs; even in the most ideal situation they can look only at neighboring part of the research front, for it is not their own business to see the whole picture. Quite apart from the fact that we have no national scientific policy, it is difficult to see any ground on which such a policy might be based. It is difficult to take advice from either the promoters of special jobs or from the scientists themselves, for their interests might well be opposed, might well be irrelevant, to the needs of the nation as a whole.

I do not know, indeed, whether one might in fact understand the crises of modern science so well as to have the power to do anything about them. I must, however, suggest that the petty illnesses of science—its superabundance of literature, its manpower shortages, its increasing specialization, its tendency to deteriorate in quality—all these things are but symptoms of a general disease. That disease is partly understood by the historian, and might be understood better if it were any man's professional province to do so. Even if we could not control the crisis that is almost upon us, there would at least be some satisfaction in understanding what was hitting us. ■

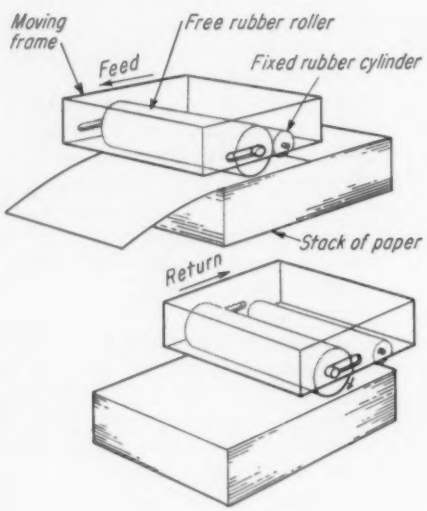
EIGHT PAPER-FEED MECHANISMS

In a world of reports, forms and memos, a prime need is to keep paper moving. Here are some ways that do the job for single sheets or continuous strip.

FRANK WILLIAM WOOD JR, *president, Advanced Designs Inc, Vienna, Va*

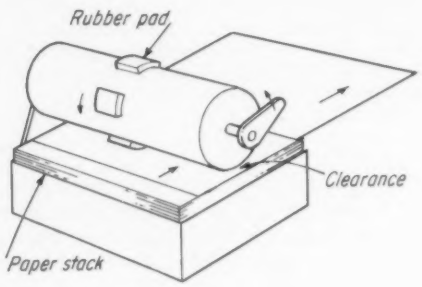
VERNAL HUFFINES, *Lofstrand Corp, Rockville, Md*

SINGLE-SHEET FEEDERS



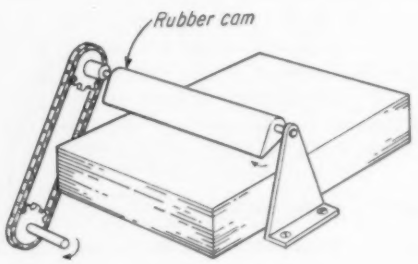
1

FREE ROLLER rides in slot. During feed it jams against the fixed cylinder and grips top sheet of paper. Return motion of frame transfers free roller to opposite end of slot, where it's free to roll back over paper.



2

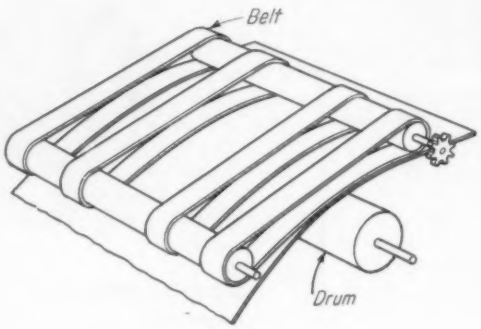
RUBBER PADS on rotating cylinder kick out one sheet per pad every revolution. Constant-force spring under paper-holder maintains proper clearance between paper and cylinder. Spacing of pads and the cylinder speed determine feed rate.



3

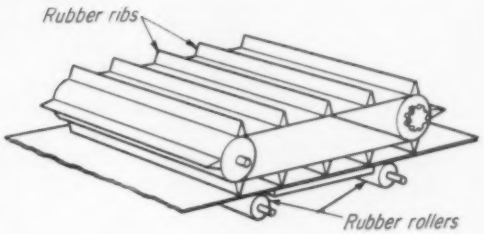
RUBBER CAM feeds one sheet each revolution. Constant-force spring under paper table keeps correct clearance. By correct timing, two or more cams in a stack will deliver different sheets in sequence. As with all single-sheet feeders, paper must be smooth enough to slide off pile.

CONTINUOUS-STRIP FEEDERS



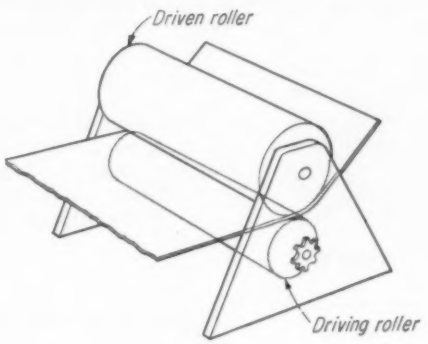
4

BELTS pressing against drum allow paper to slip and stay in alignment.



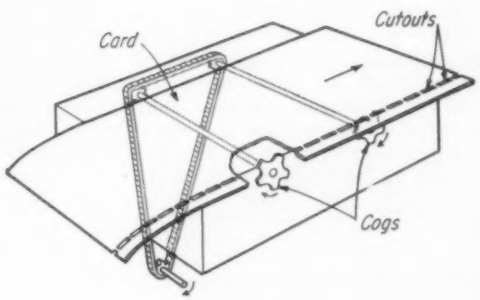
5

RIBBED BELT is another type of feed that allows paper to slip.



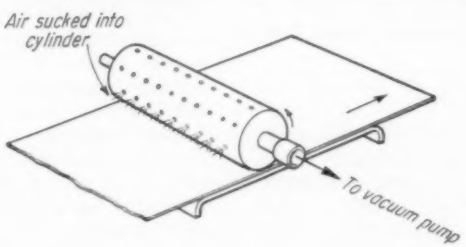
6

FRICTION ROLLERS are the commonest, cheapest way to feed paper in continuous strips.



7

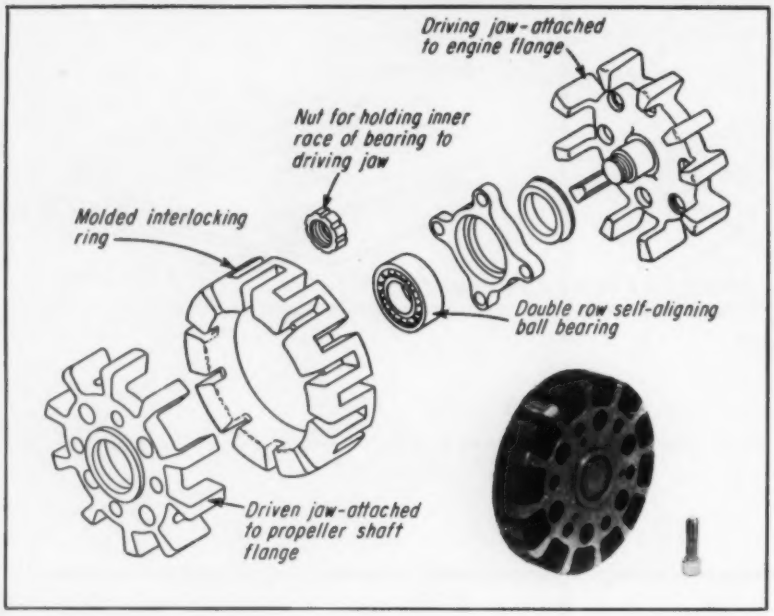
COGS fit in perforations to give positive feed with no slipping.



8

VACUUM PUMP sucks air in through the holes, holding paper against the cylinder. Intermittent operation of vacuum keeps paper from wrapping around cylinder.

SIGNIFICANT COMPONENTS MATERIALS, PROCESSES


Driving jaw-attached to engine flange
Nut for holding inner race of bearing to driving jaw
Molded interlocking ring
Double row self-aligning ball bearing
Driven jaw-attached to propeller shaft flange

Self-aligning coupling . . .

is spacer type, corrects misalignment up to 6° between engine and shaft. Thrust and pull exerted by propeller shaft is centered by self-aligning, double-row ball bearing. This results in smooth torque transmission, allowing full engine power to deliver useful torque to propeller. Synthetic-rubber interlocking ring absorbs or cushions shock, gear and other shaft vibrations and allows flexing movement between two sides of coupling. Unit has no moving parts and fits between existing flanges or directly to shafts. Five sizes range from $58 to $130. Delivery from stock or in 2 to 3 wk on special sizes. **Voges Mfg Co Inc, Ozone Park 17, NY.**

Circle 300 on Reader Service Card

Vibration-damping tape . . .

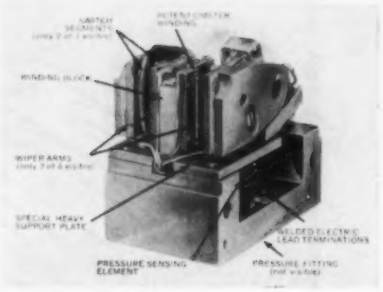
for application on thin sheetmetal, reduces resonant vibration and accompanying noise by converting vibration energy into heat. Consisting of foam, plastic and high-tack adhesive, tape conforms to rough and irregular surfaces and is applied with just finger pressure against plastic backing. Damping occurs when embossed vinyl backing (serving as constraining layer) forces polyurethane foam (between backing and adhesive) to absorb vibration energy. Tests indicate tape can withstand 50 million cycles of high-amplitude vibration. Caliper of tape is 0.250 in.; weight, 0.250 psi. Single layer dampens on steel and aluminum up to 0.060 in. thick. Available in 6-in. widths and lengths up to 8 ft at $1.55 per sq ft. **Minnesota Mining & Mfg Co, 900 Bush Ave, St Paul 6.**

Circle 301 on Reader Service Card

Variable-speed drive . . .

requires no lubrication. Bearings, sealed and shielded, are factory-lubricated, while shaft surfaces and nonmetallic bushings are made of wear-resistant materials. Since nonmetallic surfaces carry the load, fret corrosion is reportedly eliminated. Available in ¼ to 25 hp with output speeds from 4660 to 0.4 rpm in speed variations up to 10:1. Models are dripproof, totally enclosed, fancooled, or explosionproof. Prices start at $136.60 for ¼-hp, dripproof drive. One through 5-hp drives are from stock. **Sterling Electric Motors Inc, 5401 Telegraph Rd, Los Angeles 22.**

Circle 302 on Reader Service Card



Potentiometric-type transducer . . .

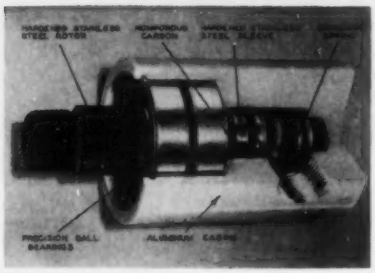
measures absolute, gage or differential pressures of corrosive or noncorrosive gases or liquids in the full-scale range of from 0 through 5 and 0 through 500 psi. Uses temperature-compensated mechanical amplification system for high-output signal. Linear or nonlinear potentiometer outputs are standard, but switch and rheostat outputs and other pickoff types can be supplied. Withstands shock of 75 g without damage, and has acceleration error of less than ±2.5% at 50 g for 0 to 5 through 0 to 10 psi and less than ±1.5% at 50 g for 0 to 15 through 0 to 100 psi. Standard model is priced at $250 each in quantities of 100 or more. Delivery in 4 to 6 wk. **Fairchild Controls Corp, Components Div, 225 Park Ave, Hicksville, NY.**

Circle 303 on Reader Service Card

Thick-section cure in 24 hours

at room temperature is possible with fluid silicone rubber. With addition of a catalyst, material sets up into a rubbery solid without heat, pressure or moisture. Variations in thickness (unlimited) are said to have no significant effect on curing rate and uniformity, while setup time can be lengthened or reduced without affecting properties of cured parts. After vulcanizing, material has tensile strength of 300 psi, elongation of 150% and a durometer hardness of 40 (42 after 7 days). Cured parts or sections can be immediately exposed to temperatures of from —100 to 500 F without threat of reversion. Bulk quantities available from stock in 5-qt containers, 6-gal pails and 10-gal drums at $4.30 per lb for 5 to 99 lbs; $4 per lb for 100 to 999 lbs; and $3.90 per lb for 1000 and over lbs. One-lb containers are priced from $4.75 to $4.95. **Dow Corning Corp, Midland, Mich.**

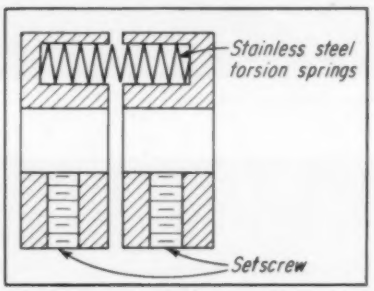
Circle 304 on Reader Service Card



Revolving joint . . .

handles 500 lb of air or hydraulic pressure with a minimum of turning torque at speeds around 1500 rpm. Has aluminum casing, hardened stainless steel rotor and nonporous carbon seat that aligns itself to rotor face. **Rotherm Engineering Co Inc, 7280 W Devon Ave, Chicago 31.**

Circle 305 on Reader Service Card



Miniature shaft coupling . . .

uses four torsion springs between two hub members to cushion starting and braking loads. Springs are housed in counterbored holes drilled in inside face of each hub member. Springs transmit torque from shaft hub to shaft hub, and permit shaft to shaft misalignment of 5° angular offset and 1/32-in. parallel offset. Available in aluminum, brass or stainless steel with bore sizes to ¼-in. dia. Over-all dimensions are ½ in. long x ⅜ in. dia. From stock at $1.90 each. **Fourdee Inc, PO Box 6006, Orlando, Fla.**

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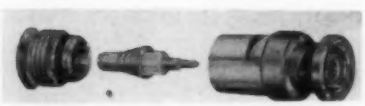
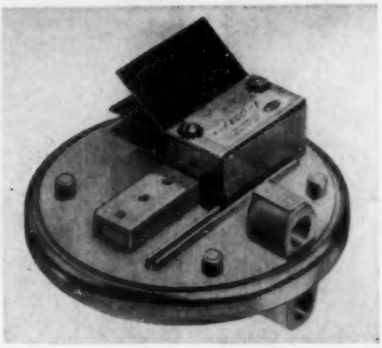


Cable-clamping connector . . .

is reported to withstand pull greater than inherent strength of cables used with it. Comprises three parts—nut, contact-wedge and body assemblies—and is pressurized to 50 psi for cables with unperforated jackets. Requires no combing or trimming of braid. Can be used with such large cables as RG-5, 8, 9/U, etc. **Automatic Metal Products Corp, 323 Berry St, Brooklyn 11, NY.**

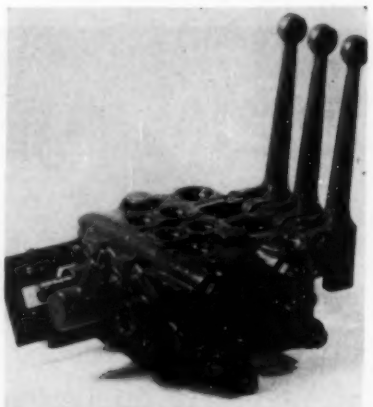
Circle 307 on Reader Service Card



Low-pressure-sensing switch

measuring only 4 in. in dia, operates from differential pressures of 0.15 to 80 in. water. Holds set point through various total pressures and can be worked from plus, minus or differential pressures in any position. Has few moving parts, and no complicated linkages, bearing arrangements or sealing devices. **F W Dwyer Mfg Co, Dept PE-1, PO Box 373, Michigan City, Ind.**

Circle 308 on Reader Service Card



Multiple-unit control valves

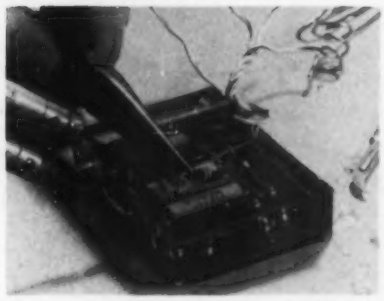
for mobile equipment, are available in any number of sections up to 10, with individual load checks in each section. Rated for operation up to 2500 psi with nominal flow rate of 15 gpm. Integral pilot-operated relief valve, with pressure settings from 500 to 2500 psi in increments of 250 psi, is said to have extremely low pressure override characteristics. **Vickers Inc, Div Sperry Rand Corp, Detroit 32.**

Circle 309 on Reader Service Card

In-line digital readout . . .

uses nearly full viewing screen to display 1⅛-in. high characters. Operates on rear-projection principle and contains 12 miniature lamps and 12 condensing lenses which carry desired word, digit or character. When one lamp at rear of unit is lighted, it projects information on corresponding condensing lens through a projection lens onto viewing screen. Multiple word messages may be used either in black and white or color. Color backgrounds also can be used with words or digits. Individual units, measuring 1⅞ x 2⅜ x 6½, can be grouped together. Priced at $18 each. Delivery in 30 days. **Industrial Electronic Engineers Inc, 5528 Vineland Ave, North Hollywood, Calif.**

Circle 310 on Reader Service Card



Silicone encapsulating resin

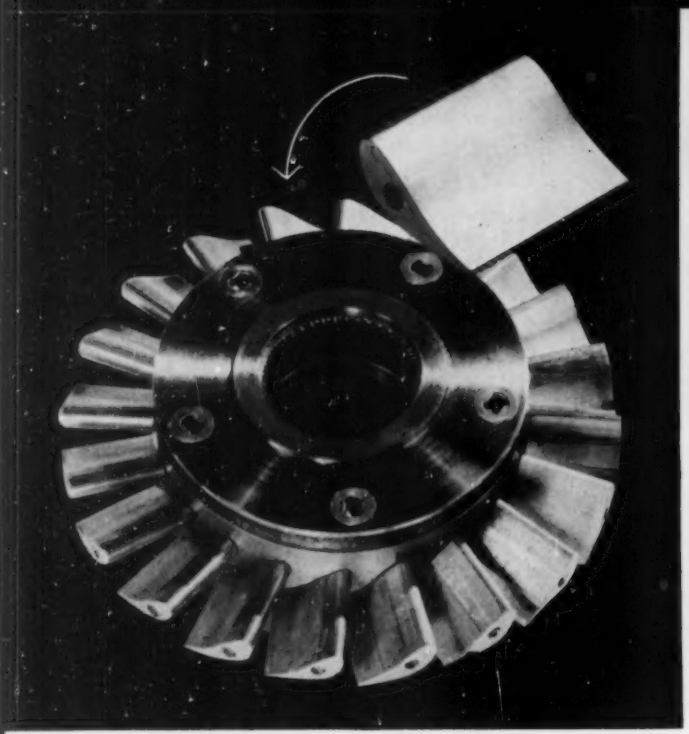
cures in place (after blending with curing agent) to form a flexible, tough, moisture-resistant transparent mass. Cured resin can be cut away from encapsulant to repair or replace (see photo) defective components. New resin poured over repaired area adheres to original material, restoring encapsulant to original condition. Suggested curing cycle is 4 hr at 149 F. Material formed shows tensile strength of from 800 to 1000 psi; Shore A Scale hardness of approx 40; and elongation in the range of 100%. **Dow Corning Corp, Midland, Mich.**

Circle 311 on Reader Service Card

Electronic control meter . . .

operates without electrical contacts and provides continuous output signal past control setting with uninterrupted full-scale indication and automatic resetting. Comprises meter movement and one oscillation and one pickup coil, both in a vertical plane. Disturbance of supersonic oscillation created between these coils by interposition of a vane creates a signal, which is amplified by transistor-equipped section. Signal remains "on" as long as pointer is beyond selected set point. When input signal to meter movement drops below control setting, signal immediately goes off, since coils are no longer shielded by movable vane. Automatic resetting then takes over, as control system

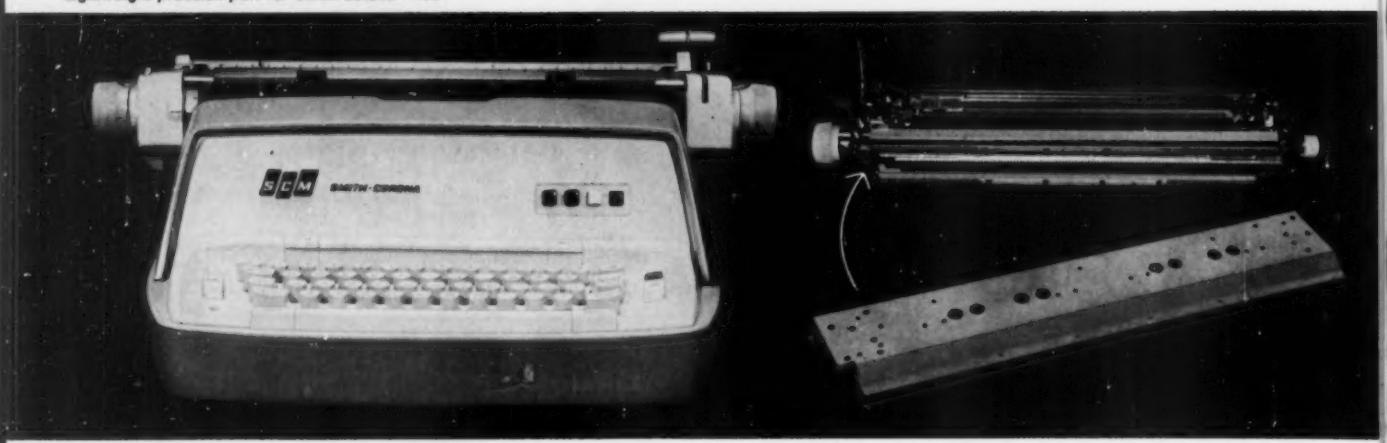
continued on page 65



Automotive transmission stator blade

Lightweight precision part for Smith-Corona "400"

Printer's furniture, The Challenge Machinery Company



ELIMINATE MACHINING, CUT PRODUCTION COSTS WITH MAGNESIUM PRECISION EXTRUSIONS

These close-tolerance parts were produced with no machining costs! They're Dow precision magnesium extrusions which require only end trimming or cutting to length before use . . . and where transverse holes are needed, drilling and tapping. Dow precision magnesium extrusions help manufacturers cut production costs, while providing tolerances as close as ± .001 inch on critical cross-sectional dimensions, dimensional stability and light weight. There is no machining on the typical parts above . . . component for the ultra-modern Smith-Corona "400" Office Electric Typewriter; The Challenge Machinery Company's printer's furniture; and automotive transmission stator blade. Precision magnesium extrusions can be produced with sharp V's, thin notches, and accurate serrations. Complex parts can be given a consistent precision fit. For information, write to THE DOW METAL PRODUCTS COMPANY, Midland, Michigan, Merchandising Dept. 1104DZ3-6.

DOW

THE DOW METAL PRODUCTS COMPANY

Division of The Dow Chemical Company

CIRCLE 64 ON READER SERVICE CARD

DOW

NEW DOW MAGNESIUM ALLOY ZE10A

high welded joint strength and no stress relief!

New Dow magnesium alloy ZE10A needs no post-welding stress relief. This strong sheet alloy is ideal for fabricating containers, vehicle bodies and other structures . . . and for field repair operations where stress relief can be a real problem.

ZE10A provides very high welded joint strength, important in butt welding of plates. The result—strong, stiff weldments of very light weight . . . with greater capacity, pound-for-pound, than structures made from any other metal!

To weld ZE10A sheet to extrusions, use Dow extrusion alloy ZK21A. No stress relief required. For further information and data, write THE DOW METAL PRODUCTS COMPANY, Midland, Michigan, Merchandising Dept. 1152DZ3-6.

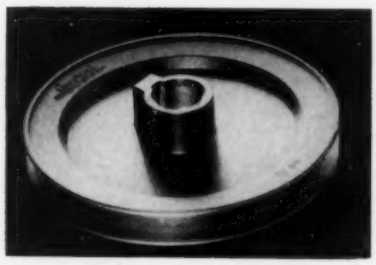
ZE10A makes light, strong containers, like this Tote Bin, built by Tote Systems, Inc., Beatrice, Neb., a subsidiary of Hoover Ball and Bearing Company.

DOW

THE DOW METAL PRODUCTS COMPANY
Division of The Dow Chemical Company
Midland, Michigan

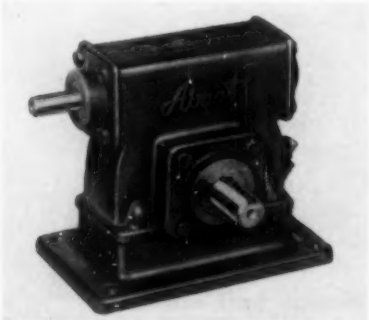
goes off or on depending upon direction of pointer travel. Available in two models, with single or two independent control-arm circuits. Both require power input of 22½ v dc at 10 ma for switching circuit. **International Instruments Inc**, PO Box 2954, New Haven 15, Conn.

Circle 312 on Reader Service Card



Driver pulleys . . .
have heavier cross-sections in area where flanges merge. This is said to give pulleys 20% greater strength than previous models. Statically and dynamically balanced units are available in ½-, ⅝-, ¾- and 1-in. bores with standard keyway and in diameters from 1½ to 16 in. **Congress Drives Div, Tann Corp**, 3750 E Outer Dr, Detroit 34.

Circle 313 on Reader Service Card



Fractional-hp speed reducer
provides speed ratios from 5¾:1 to 100:1, handling inputs of ¼ to 2 hp at 1800 rpm and ⅛ to 1½ hp at 1200 rpm. Right-angle drive, horizontal worm-gear unit for continuous duty can be furnished with input or output shafts projecting from either side of semi-steel housing, or from both sides. From stock. **Abart Gear & Machine Co**, Dept PE-1, 4834-36 W 16th St, Chicago 50.

Circle 314 on Reader Service Card

Speed-sensing switches . . .
for multispeed rpm control, make or break electrical circuits at predetermined speeds and contain centrifugal governors which actuate from 1 to 4 snap-action

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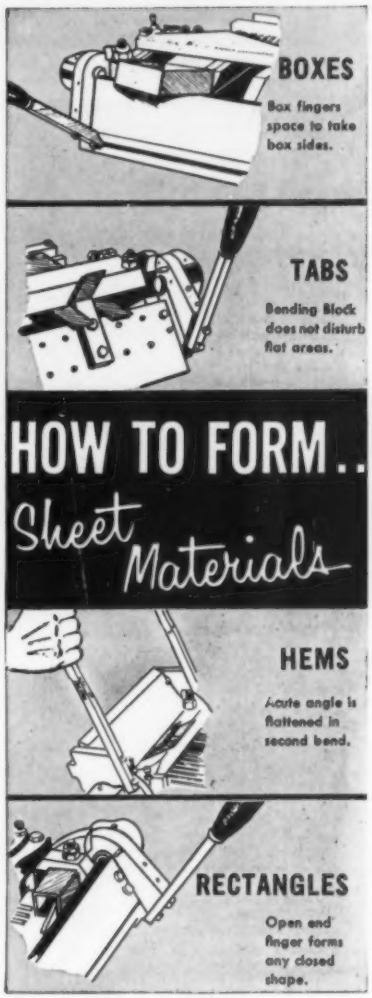
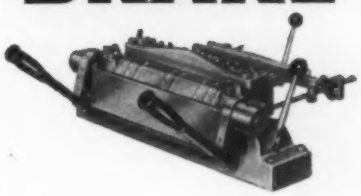


with a

DI-ACRO BRAKE



The Di-Acro Brake is a six-in-one precision metal working machine simply tooled for a variety of jobs. Ten models in 6", 12", 18" and 24" widths handle up to 16 gauge mild sheet steel.

Consult the yellow pages of your phone book under machinery, machine tools for the name of your Di-Acro distributor or write for 16 page "Handy Guide" to . . . Di-Acro Brakes.

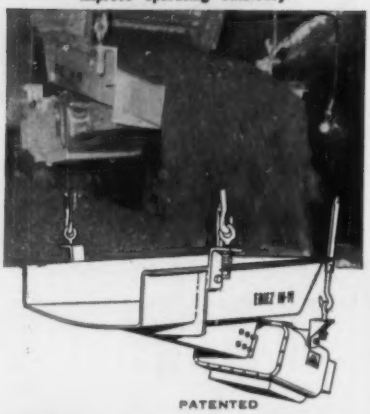
pronounced die-ack-ro

di-acro PRECISION METALWORKING MACHINES

DI-ACRO CORPORATION
(Formerly O'Neil-Irwin Mfg. Co.)
833 Eighth Avenue
Lake City, Minnesota

ERIEZ *Magnetic Minute*

60 seconds that will help you improve operating efficiency.



PATENTED

HOW TO BUILD A PLUS INTO HEAVY-DUTY MATERIALS HANDLING EQUIPMENT

If the problem is feeding large tonnages of bulk materials with accurate control, consider including Eriez patented heavy-duty vibratory feeders in your new designs for materials handling equipment.

No rectifier is needed with Eriez AC powered feeders. Totally enclosed electro-permanent magnetic drive is ideal for hazardous, dusty, wet, and corrosive installations. New fibre glass springs assure superior performance and control . . . longer life because spring breakage is practically eliminated. Heavier, more rugged construction withstands severe operating conditions. Simple, compact controls require less wiring and installation time.

Illustration shows one of a number of Eriez units available for heavy feeding applications where big capacity and accuracy are essential. Eriez Hi-Vi® vibratory feeders include models with feeding capacities ranging from ounces to many tons per hour.

Write for descriptive bulletin to:

ERIEZ MANUFACTURING CO.
107QB Magnet Drive, Erie, Pa.

MAGNA-THOUGHT

Companies using Eriez components know we will remain faithful suppliers — not potential competitors.

R. F. MERWIN
President

ERIEZ

A GROWTH COMPANY . . .
10 NEW PRODUCTS IN THE LAST 5 YEARS

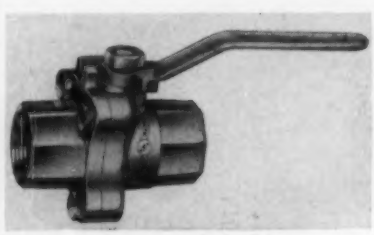
switches, depending on model, within close speed tolerances. Repeatability and differential reportedly can be held as low as 1% or less. Operating ranges are between 700 and 5000 rpm or higher. Each measures 1¾ in. high and 2½ in. sq and weigh 15 oz or less, depending upon model. **Kahn & Co Inc, PO Box 516, Hartford 1, Conn.**

Circle 315 on Reader Service Card

Lockout hub . . .

added to front driving axle, makes it possible to disengage front wheels when not required. Designed for four-wheel-drive trucks and light vehicles in the ¼-, ½- and ¾-ton range. Twist of control knob locks spring-loaded device in place. No rocking of vehicle is required. **Dana Corp, Toledo 1, Ohio.**

Circle 316 on Reader Service Card



Bronze ball valve . . .

has spring, retainer ring and O-ring seal behind valve seat for constant compression, self-adjustment and tight seal even on low pressure and vacuum lines. Said to be priced slightly higher than standard bronze gate valve. **Ball Valves Inc, 41 Jackson St, Worcester, Mass.**

Circle 317 on Reader Service Card

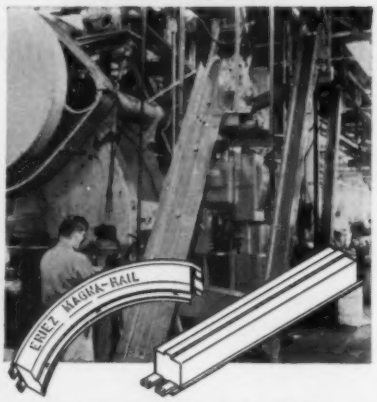
Battery-powered motor . . .

for 9-v operation, has less than 2% variation in speed and power consumption of only 25 ma in neutral position. Also said to provide top control when voltage goes down to 6 or up to 12. Governor-regulator has torque measured at a constant 1500 rpm. (variations of 600 to 700 rpm centered on 1500 rpm can be made with simple screw adjustment). For ap-

continued on page 68

ERIEZ *Magnetic Minute*

60 seconds that will help you improve operating efficiency.



HOW TO BUILD A PLUS into PLANT AUTOMATION systems

You can often boost the sales appeal and value of your equipment by incorporating Eriez Magnamation® (magnetic automation) components.

For example — Eriez Magna-Rails fastened under conveyor belts provide safe, positive hold of ferrous parts. They swiftly convey, control, and elevate parts up or down inclines as steep as 90°; increase safety and reduce damage by preventing slippage; save valuable floor space by permitting shorter belt spans and closer grouping of machines.

Magna-Rails are available with or without extruded aluminum covers — in 3 standard strengths and increments of up to 8′ in any one section. Assembly width is 4″.

Eriez broad experience with OEMs, designers and direct users is available to assist you in the application of magnetic components to materials handling equipment. Write to:

ERIEZ MANUFACTURING CO.
107QA Magnet Drive, Erie, Pa.

MAGNA-THOUGHT

By using exactly the right magnetic material for a given application. Eriez can provide each customer with precisely the right equipment to do a particular job.

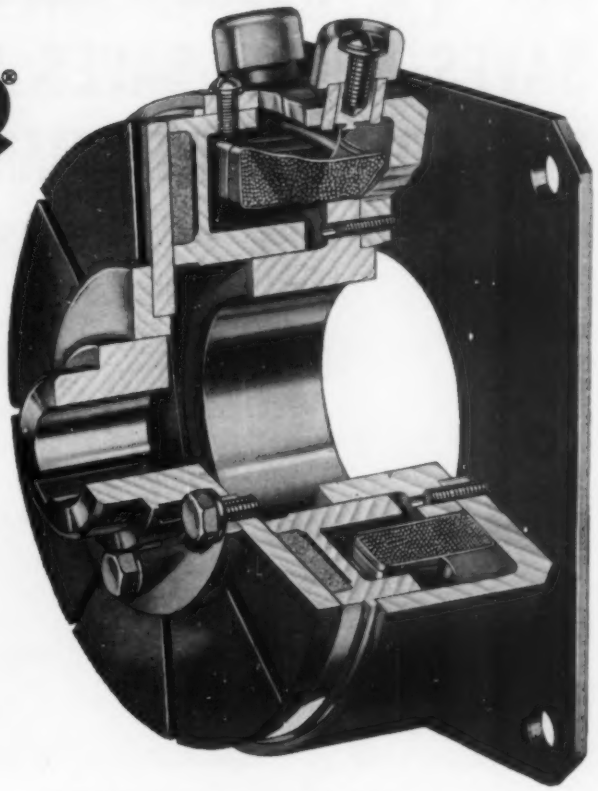
W. J. FALLER
Product Mgr. Automation

ERIEZ

A GROWTH COMPANY . . .
10 NEW PRODUCTS IN THE LAST 5 YEARS

THE GENTLE MEANS OF CONTROL FOR STOP-AND-GO MACHINES!

EATON DYNA-TORQ® Magnetic-Friction Clutches and Brakes



Eaton Dyna-torQ Magnetic-Friction Clutches and Brakes provide a simple, accurate, shock-free method of controlling power and motion in today's complex production and processing machines—or for equipment you may now have in the design stage.

Dyna-torQ units utilize the simple principle of electro-magnetic engagement of two friction members (field-magnet and armature) to transmit driving or braking torque.

Extremely rapid response without backlash or chatter makes Dyna-torQ units ideally suited to a wide range of automatic cycling applications.

Carefully selected and tested materials, high quality of workmanship, and important design features provide long operating life, minimum down-time, and low maintenance cost.

Dyna-torQ units are offered in a diversified line including clutches, brakes, clutch-brakes, and clutch couplings. Sizes range from 1½" to 15" in diameter. They are easily and quickly installed on new machines or existing plant equipment.

INSTANT RESPONSE: Short armature travel—1/32"—and the direct pull of the magnetic field on the armature eliminate any need for mechanical linkage; prevent backlash and lost motion.

INSTANT RELEASE: Dyna-torQ design permits instant release of armature when field coil is de-energized; there is no residual flux to delay action.

HIGHLY EFFECTIVE COOLING: Fanning action of armature carries heat away from unit; reduces operating temperature.

NO ADJUSTMENT: Proper clearance between the armature and field magnet is maintained automatically.

SIMPLE, ACCURATE CONTROL: Closely held rate of acceleration and deceleration prevents shock to gear trains and other linkage. Small, compact Dyna-torQ controls rectify alternating current to furnish direct current for the coil of the field magnet assembly.

INTERCHANGEABLE PARTS: Corresponding parts of all Dyna-torQ units of a given capacity are interchangeable.

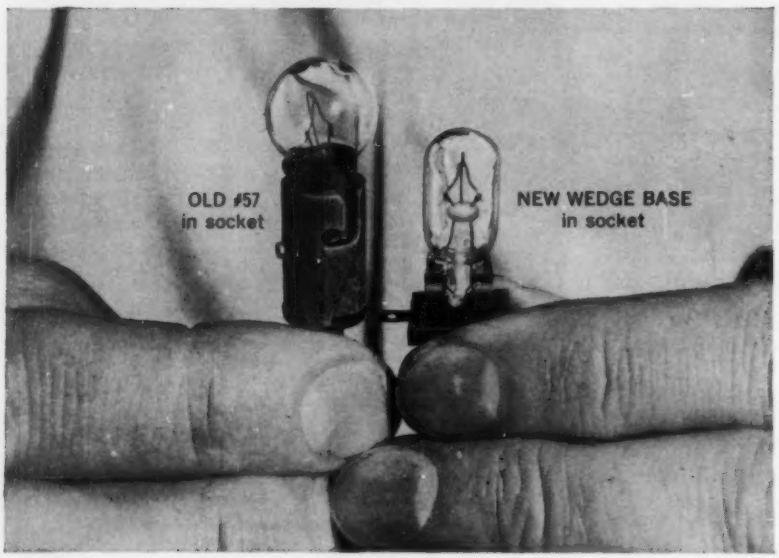
Send for Illustrated Literature Covering the Complete Dyna-torQ Line

EATON MANUFACTURING COMPANY
DYNAMATIC DIVISION
3122 FOURTEENTH AVENUE • KENOSHA, WISCONSIN

ORIGINATORS OF EDDY-CURRENT SPEED CONTROL EQUIPMENT

CIRCLE 67 ON READER SERVICE CARD 67

NEW G-E "WEDGE BASE" LAMP SAVES SPACE, SAVES MONEY, SAVES TIME, SAVES MANPOWER



The new "Wedge Base", all-glass, incandescent indicator lamp is an exclusive G-E development designed to replace the old #57 and other similar bayonet-based lamps. It's available in 6.3 and 12 volts. See below.

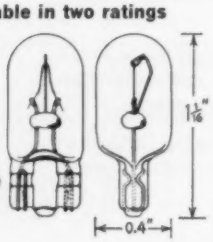
The Wedge Base saves space because, with its holder, it is considerably smaller than the old #57. It saves money because the holder and total installation costs are less. It saves time because the holder is easier to install and the lamp can be seated with just a push. And it saves manpower because installation can be automated and holders can be molded into plastic circuits. The G-E Wedge Base lamp can withstand ambient temperatures up to 600°F because it has no basing cement.

A major automobile manufacturer is already using G-E Wedge Base lamps; they're available in mass quantities. For more information write: General Electric Co., Miniature Lamp Department M-12, Nela Park, Cleveland 12, Ohio.

The Wedge Base is available in two ratings

G.E. Lamp No.	158	159
Circuit Volts	12	6.3
Amperes	0.24	0.15
Design Volts	14	6.3
Rated Av. Life at design volts	500 Hrs.	*
Filament	C-2V.	C-2R
L.C.L.	½"	½"
Bulb	T-3¼	T-3¼
Base Type	Wedge	Wedge
Candlepower	2	.35

*In excess of 5000 hrs. at 6.6 volts

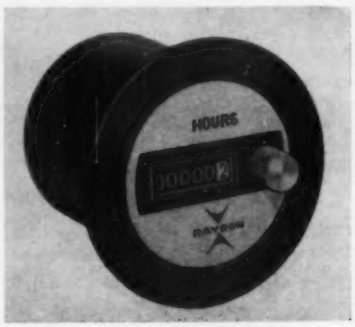


Progress Is Our Most Important Product

GENERAL ELECTRIC

plications requiring speeds higher than 1500 rpm, governor can be removed to obtain up to 4000-rpm rating. Vibrating stainless steel blade in governor reportedly offers high dimensional stability when subjected to heat or cold. **Jonard International Inc, 624 Madison Ave, NYC.**

Circle 318 on Reader Service Card

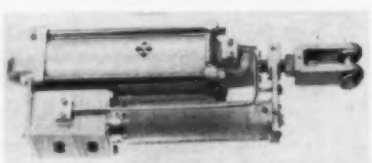


Elapsed-time indicator . . . registers hours and tenths as well as minutes and tenths to 99999.9. Resettable and nonresettable models are available, both with 3½-in. dia round bezel or with 3 x 3 in. sq bezel. Equipped with screw type terminals, unit operates at 120 or 240 v ac, 50 or 60 cps. Input is 5 w at 60 c or 3.4 w at 50 c. Said to be priced considerably lower than most comparable units. **Haydon Div, General Time Corp, 245 E Elm St, Torrington, Conn.**

Circle 319 on Reader Service Card

99.999+% pure silver . . . is available in fine crystalline powder. Also can be supplied to specifications in vacuum cast ingots or rolled into strip or foil. Silver's only spectrographically detectable elements are iron, copper, silicon and manganese—all less than one part per million each. **High Purity Metals Inc, 340 Hudson St, Hackensack, NJ.**

Circle 320 on Reader Service Card

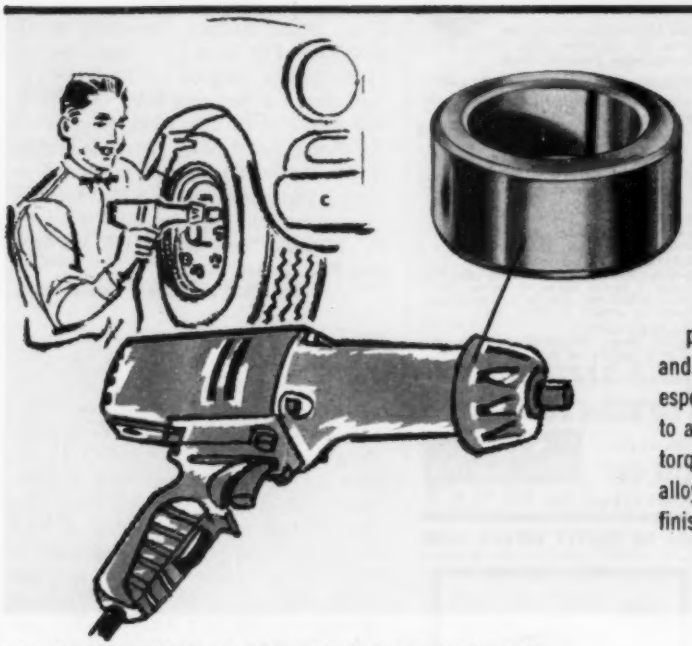


Power positioner . . . controls unbalanced loads up to 150 lbs. Has 2½-in. bore and 5-in. stroke and drives valves, dampers or other control devices with a ±1% accuracy. Requires only 1.5 sec for full stroke movement with 100 lbs of air supply and no load. Frequency response is 1.3 cps with no load at 10% peak-to-peak input signal. At 5% peak-to-

continued on page 70

600 SERIES

THE FORGEABLE BEARING ALLOYS THAT STAND UP ON THE REALLY TOUGH JOBS!

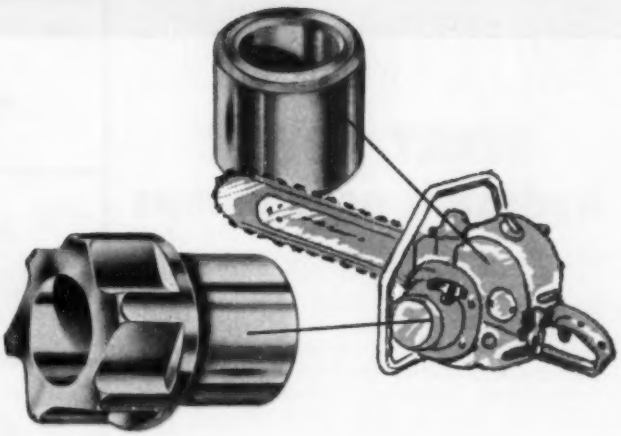


600 ALLOY NOSE BEARING WITHSTANDS THE PUNISHING SHOCK LOADS OF AN IMPACT WRENCH

This heavy-duty impact wrench takes the rigorous punishment of hard industrial use right on the nose . . . and right on the 600 Series nose bearing. This bearing was especially chosen by the manufacturer because of its ability to absorb a range of 1600 to 1800 impacts per minute at a torque of from 0 to 250 foot pounds. By specifying 600 bearing alloy, the manufacturer gets superior performance from his finished product.

600 ALLOY RATCHET AND DRIVE GEAR BEARING TAKES THE TERRIFIC POUNDING OF A HIGH POWERED CHAIN SAW

Professional woodcutters give chain saws a rough time for hours on end, all year round, and these rugged saws must be built to take punishment. With chain speeds up to 3000 feet per minute, the ratchet and drive gear bearings, for example, must have a very high strength, hardness and good resistance to wear with minimum lubrication. That's why 600 Series Alloy was specified for both parts . . . the ratchet is a forging and the bearing was produced from 600 Series rod.



MUELLER BRASS CO. SPECIALIZES IN ALLOYS FOR DIFFICULT APPLICATIONS

For complete engineering data, write today for Special Alloys Kit No. 13.

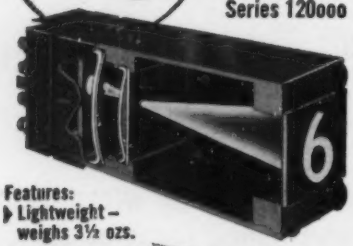
The alloys available from the Mueller Brass Co. range from those having high hardness and wear properties, to alloys that must possess excellent electrical conductivity, and ones that must have free-machining properties. Let our engineers help you select the alloy best suited to your exact application.

MUELLER BRASS CO. PORT HURON 29, MICHIGAN

326

MINIATURIZED! LIGHTWEIGHT!

IN-LINE DIGITAL READOUT
Series 120000



Features:
- Lightweight – weighs 3½ ozs.
- Quick disconnect at rear for easy lamp replacement.

PRICE COMPLETE $35.00

Quantity Prices On Request

WRITE TODAY FOR COMPLETE SPECIFICATIONS

Representatives in principal cities

Over 1000 firms throughout the world in just a few years prove unprecedented acceptance of IEE digital readouts.

INDUSTRIAL ELECTRONIC ENGINEERS, Inc.
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NORTH HOLLYWOOD, CALIF.
IEE

CIRCLE 205 ON READER SERVICE CARD

Another Use for Schnorr Disc Springs

Eliminate Fatigue, Settling, Creeping

The Auto Union 1000 sedan distributed in United States by Mercedes Benz Sales, Inc. Division of Studebaker Packard Corp.

SCHNORR SPRINGS PROVIDE UNLIMITED LIFE!
Check these exclusive features:

- **ADJUSTMENT**— SCHNORR SPRINGS provide different pressure and deflection with exacting adjustment. ALL FROM ONE SIZE.
- **COMPACTNESS**— Great power is concentrated in a very small space.
- **ABSORPTION**— Dampens impacts and minimizes after-oscillation.
- **VERSATILITY**— SCHNORR SPRINGS can be easily adjusted to provide a varied range of spring pressures and deflections. The springs may also be stacked to provide multiple force.
- **SPECIALIZATION**— SCHNORR DISC SPRINGS may be obtained in a variety of sizes for specialized tasks. MODEL K is especially adaptable to eliminate noise and play in ball bearings.

Further Information and Literature on SCHNORR DISC SPRINGS is available from:

Exclusive Distributor
KARL A. NEISE, Inc.
NEISE MODERN TOOLS
Dept. PE, 404 4th Avenue, New York 16, N. Y.

CIRCLE 206 ON READER SERVICE CARD

NOW FOUR MODEL GROUPS

BERRY/DOWTY* hydraulic gear pumps

Pressures to 3000 PSI / Outputs: 1/2 to 85 GPM

Berry's wide range of pump operating speeds, pressures and temperatures allows you to select the unit to meet your exact requirements. Metered, pressurized lubrication assures you of trouble-free performance. Volumetric efficiency of 95% at 2000 PSI minimizes input horsepower.

Berry HYDRAULICS
A DIVISION OF OLIVER TYRONE CORPORATION

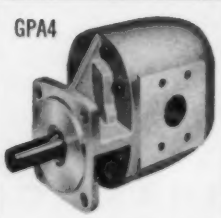
*Dowty is the tradename of Dowty Hydraulic Units Limited, England.

GPA1

GPA2

GPA3

GPA4



MAIL FOR CATALOG
Berry Hydraulics, Corinth 1, Mississippi
Name
Company
Address

peak, frequency response is 0.5 cps. Designed for indoor or outdoor operation, unit operates in ambient temperatures of up to 170 F. **Controls Div, Hagan Chemicals & Controls Inc, Hagen Center, Pittsburgh 30.**

Circle 321 on Reader Service Card

Rotary indexing table . . .

provides whole-degree angular indexing to ½ sec of arc accuracy (equivalent to 12 millionths of an in. at 20 in. dia). Seven-in.-dia unit is designed for smaller work. Table top and base each have 360 ground and lapped teeth that mesh for positive positioning and locking. Lever is shifted to raise table, and top then is rotated to desired angle indicated by scale. Over-all dimensions, including base, are 8 x 8 x 9⅞ in. **Michigan Tool Co, 7171 E McNicholas Rd, Detroit 12.**

Circle 322 on Reader Service Card

Size-5 servomotor . . .

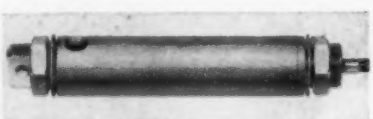
powered by 26-v, 400-c reference voltage, has no-load speed of 10,000 rpm. Torque-at-stall registers 0.1 oz-in., while rotor inertia is 0.18 gm cm², providing acceleration-at-stall of 39,000 rad/sec². Operates over ambient temperature range of −67 to 266 F. Max operating temperature is 392 F. Unit measures 0.865 in. long and weighs 0.6 oz. **Helipot Div, Beckman Instruments Inc, 2500 Fullerton Rd, Fullerton, Calif.**

Circle 323 on Reader Service Card

Single solenoid 4-way valve

works with less than 10 psi in air line. Fast-acting, ⅛-in. unit has no springs in main body, permitting full line air flow. Operates on pressures up to 150 psi (higher pressures on request). Over-all dimensions: 3½ in. high x 2⅞ in. sq. **Acro Air Associates, 16736 Foothill Blvd, San Leandro, Calif.**

Circle 324 on Reader Service Card



Miniature, heavy-duty cylinder

with ⅞-in. bore, is for 250-psi air, 2500-psi hydraulic service. Available in 1-in. stroke spring return and 1-, 2-, 3-, 5-, 7- and 9-in. double-acting models. Power factor is 0.60, giving 60 lb force at 100 psi; 1500 lb force at 2500 psi. Has fine thread screw-together construction and replaceable parts and seals. Ports are standard

⅛-in. NPT on cylinder side. **Clippard Instrument Laboratory Inc**, 7309-P Colerain Rd, Cincinnati 39.

Circle 325 on Reader Service Card

Aluminum knobs and hubs . . .

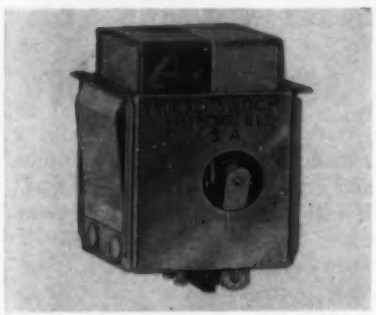
with polished surfaces or black enamel finishes, have concentricity of 0.0015 TIR between shaft hole and step dia. Furnished with two stainless steel set screws. From stock. **Ackerman Engravers**, 458 Broadway, New York.

Circle 326 on Reader Service Card

600-v relays . . .

control small, self-protected electric motors up to ¾ hp. Also can be used with horns, buzzers, lights, electronic equipment, solenoids and valves. Available with 6-, 12-, 24-, 115-, 320-, 440 and 550-v coils, 60 or 50 c. **General Electric Co**, Schenectady 5.

Circle 327 on Reader Service Card



Tiny pushbutton switch . . .

smaller than 1 cu in., offers single- or two-color indication. Each half of divided display screen has its own light source, and with 5 colors available, single switch can have any one of 15 color combinations. Lamps light up switch even under high ambient light levels. Unit contains two SPDT sub-subminiature switch elements rated at 7 amp resistive and 25 amp max inrush at 25 v dc; 7 amp resistive and 15 amp inrush at 115/230 v ac. Fitted with spring clips for quick insertion and removal from mounting holes. From stock at $16 each. **Micro Switch Div, Minneapolis-Honeywell Regulator Co**, Freeport, Ill.

Circle 328 on Reader Service Card

Modular-type pushbutton . . .

switches and pilot lights are available with four-color illumination and contact arrangements up to 8 PST. Action is solenoid, momentary, alternate-action, interlocking and lockout. Fit ⅞-in. sq panel space (¾-in. sq button). **Luminator Inc, Display-Control Div**, Costa Mesa, Calif.

Circle 329 on Reader Service Card

continued on page 73

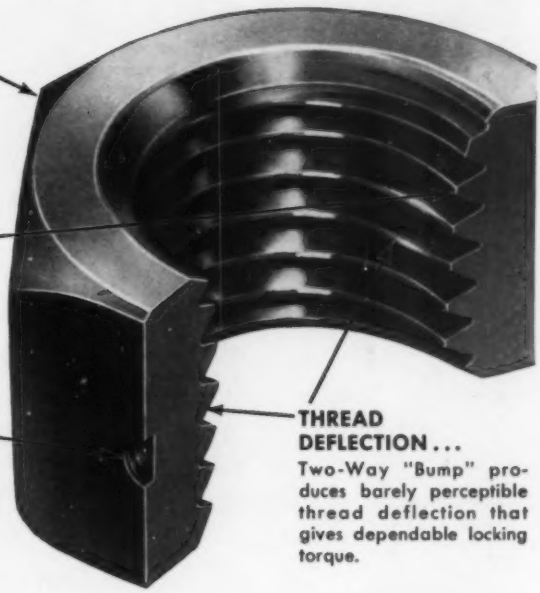
THE ANATOMY OF AN MF TWO-WAY LOCK NUT

reveals why it can improve your product and simplify fastening

DOUBLE CHAMFER . . .
The Two-Way is always right side up. Ideal for hand or hopper feed.

THREAD PROFILE . . .
More care in tapping produces threads that far exceed industry's minimal standards.

THE "BUMP" . . .
Puts the lock in the *center of the nut*. Does not affect top and bottom threads—permits easy starts. Allows bolt end to be flush with, or below, top of nut.



THREAD DEFLECTION . . .
Two-Way "Bump" produces barely perceptible thread deflection that gives dependable locking torque.

MF TWO-WAY LOCK NUTS AVAILABLE AS:

HEX NUTS

Sizes: No. 6 thru 1¼"

FLANGE NUTS, All Sizes

OPEN END CAP NUTS

Write for MacLean-Fogg CATALOG —or see it in Sweet's

MAC LEAN-FOGG MF LOCK NUTS

MacLean-Fogg Lock Nut Company
5535 N. WOLCOTT AVENUE
CHICAGO 40, ILLINOIS

Select from over 3,500 different SOLENOID VALVES from VALCOR

Series SV-54 (3 way-4 way) general purpose solenoid valves for air, oil and water. Rugged construction, yet inexpensive. Multi-million cycle life. Pressure ratings up to 150 psi. Nylon seat outlasts steel. Infinite varieties available . . . lists as low as $10.75.

Series SV-61 (2 way) Nylon body valve is ideal for general purpose and OEM installations where millions of operating cycles are vital. Nylon seat and port threads outlast steel, yet cost less. Non-corrosive, shock-resistant, proof-pressure.

Series SV-5100 Specifically designed to handle the most corrosive media in industry. Manufactured in Teflon, PVC and Nylon varieties. Diaphragm construction prevents media contact with any metal. Available in direct-acting or piloted models.

VALCOR SOLENOID VALVES

FREE...new 16 page brochure —lists over 500 corrosive media—coded for correct valve selection.

For complete information on these or other models, write or call:

VALCOR ENGINEERING CORP.

5375 Carnegie Ave., Kenilworth, N. J.
CHestnut 5-1665

Wallex Casting on Tail Skid Protects Navy Jet Fighter

When navy jets land on pitching ships, jet tails sometimes hit and scrape the deck. To protect both the aircraft and the deck, McDonnell puts smooth pads on the tail skids of its Demon jet fighter. Cast of wear-resistant Wallex alloy, these pads rebuff impact and corrosion, create little friction to mar flight decks.

Curved Wallex casting brazed to steel plate forms tail skid pad assembly.

As our example above shows, the proper functioning of a whole assembly can often be insured by protecting just one small area from damaging wear. Castings of various Colmonoy alloys are doing just that, in hundreds of places. Colmonoy nickel, cobalt, and iron-base alloys are also applied as welding rod, electrodes, paste, and as Sprayweld Powder. Learn more about this remarkable group of alloys.

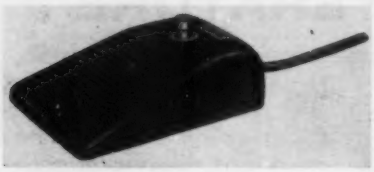
Ask for Colmonoy Hard-Facing Manual No. 79.

HARD-SURFACING & BRAZING ALLOYS

WALL COLMONOY CORPORATION

19345 JOHN R STREET • DETROIT 3, MICHIGAN

Buffalo • Chicago • Houston • Los Angeles • Morrisville • New York • Pittsburgh • Montreal • London, England



Footswitches . . .
available in maintained and momentary contacts, are rated from 6 to 20 amp. From stock at $7.95 each, depending on quantity. **Vemaline Products Co, Franklin Lakes, NJ.**

Circle 330 on Reader Service Card

Wound-rotor motors . . .
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measures pressure, torque and thrust loads from 0 to 10,000 lb (available in other types from 0 to 1000 lb, 0 to 4000 lb). Has static piston with 0.030-in. travel, full load. Ten-lb unit operates at temperatures from 0 to 220 F. **Research Products Co, PO Box 1047, 1415 3rd St South, St Petersburg 31, Fla.**

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has three scales calibrated in both oz-in. and gram-centimeters which provide a measuring range of 0.5 to 40 oz-in. (20 to 2800 gm-cm) at an accuracy of ±0.2% of indicated reading. Uses weight-vector principle (no springs). Dimensions are 14¼ x 16 x 8 in. Weight: 24 lb. **Waters Mfg Inc, Wayland, Mass.**

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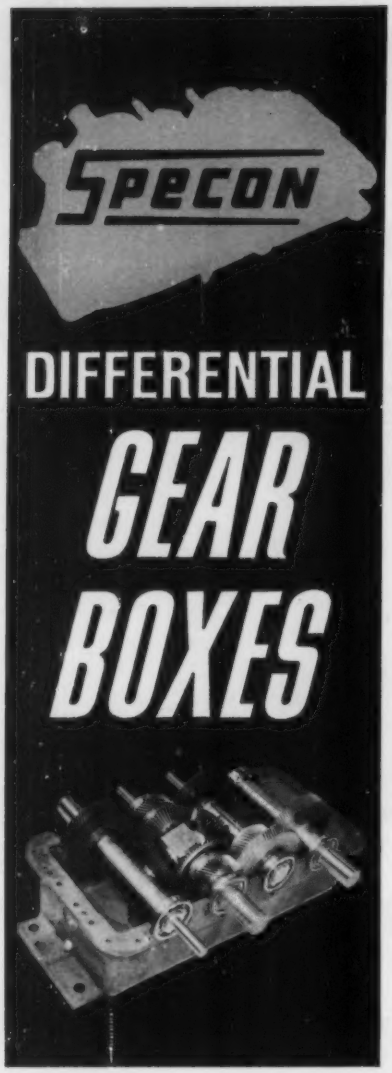

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DESIGN LITERATURE

Basics of Analog Computers

T D TRUIT and A E ROGERS. John F Rider Publisher Inc, 116 W 14th St, New York 11. 6 x 9, 378 pp. $12.50.

Though aimed at a reader without much technical background, the design engineer will still find this a highly readable introduction to these computers, how they work and what they can do. Like some other Rider technical books, it uses numerous pictures and sketches to illustrate the main points, much as an instructor uses a blackboard. Unlike the other books of this series, this one has a hard cover.

The frequent excursions into the fundamentals are more often annoying than helpful. Because of the assumed technical level of the reader, the authors feel obliged to explain such things as analogs, integration and vacuum tubes. Fortunately, the sketches enable you to scan quickly and get the gist without wading through the text.

The book is divided into three parts: principles and techniques; the general-purpose computer; programing and applications. The first section is just background and can be scanned quickly. The second section describes computing circuits and mechanisms, how they work and the mathematical functions they perform. The third section tells how a computer made up of these building blocks can be applied to practical problems. The book is not sufficiently detailed to help you with a complex design problem, but there's enough here to tell you whether, and how, it might be solved.—CJL

Elevated-temperature Properties of Aluminum and Magnesium Alloys

HOWARD R VOORHEES and JAMES W FREEMAN. American Society for Testing Materials, 1916 Race St, Philadelphia 3. 8¾ x 11, 308 pp. $7. Price to ASTM and ASME Members: $5.60.

This report is the most complete compilation of data available today on the subject. It summarizes elevated-temperature properties from a number of sources and presents them in tables and charts. The massive report assumes a knowledge of how to use the contents, because no attempt is made to interpret the test data. Nor are the values given always usable as guaranteed minimums. But if you want property data on aluminum or magnesium alloys that are suitable for elevated-temperature applications, you should be able to find it here.

Instrumentation and High-speed Photography

Society of Motion Picture and Television Engineers, 55 W 42nd St., New York 36. Paper bound, 8 x 11, 187 pp. $4.

Compilation of papers reprinted from the SMPTE Journal. Subjects span the entire field of high-speed photography: light sources, optics and visibility studies, cameras and accessories, properties and uses of cathode-ray tubes, television systems in instrumentation, very high-speed systems, processing and processing machines, and applications in military and industrial testing.

In addition to the 43 papers, the book includes abstracts of the papers in French and German, and concludes with a cumulative index of all six volumes in Series I.

Other Books of Interest

Standards of the Hydraulic Institute, 10th Edition

First Revision. Hydraulic Institute, 122 E 42nd St, NY 17. 8½ x 11, 75 pp. $1.25.

Predicted Behavior of Rapidly Heated Metals in Compression

TR R-59. E Z Stowell, G J Heimerl. Sup of Documents, US Govt Printing Office, Washington 25, DC. 8 x 10¼. 30¢.

Recommended Dimension Identification Code for Fluid-power Cylinders

National Fluid Power Assn, 5595 N Hollywood Ave, Milwaukee 17. 8½ x 11, 24 pp. $1.

ABSTRACTS FROM THE LITERATURE

Minimum-weight Springs

Procedure in this paper is for designing helical compression springs with minimum weight. It differs from other procedures by using more universally applicable assumptions.

"Optimum Design of Helical Compression Springs," by R. J. Erisman, International Harvester Co. American Society of Mechanical Engineers paper 60-WA-215, 29 W 39th St, New York 18.

continued on page 77

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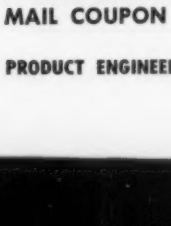

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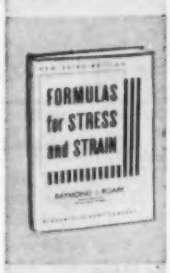

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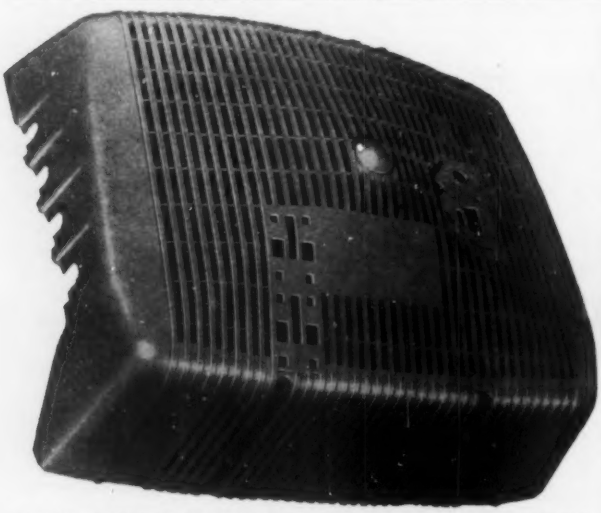

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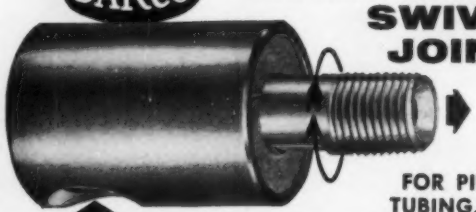

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Balancing Flexible Rotors

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"Balancing Flexible Rotors," by A. H. Church, New York University, and R. Plunkett, General Electric Co. American Society of Mechanical Engineers paper 60-WA-13, 39 W 39th St, New York 18.

Mold Fabrication

There are three main areas of consideration in a discussion of the reduction and control of cost in mold fabrication; first, those moldmaking costs which are affected by the product's design requirements; second, costs which are incurred as a result of the mold design; and third, costs resulting from the methods and procedures planned for the actual construction of the mold. Each area is analyzed separately. Methods of procedure and suggestions concerning the control and reduction of cost are here developed.

"Mold Fabrication—Cost Reduction and Control," by Rolf H. Berg, v-p & treas, Atola Tool & Mold Corp. SDCE Paper No 3, presented at 1st SDCE Congress, Nov '60. Society of Die Casting Engineers Inc, 19382 James Couzens Highway, Detroit 35.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

MINIATURE AND INSTRUMENT BEARINGS—Catalog, 40 pp. Discusses selection of ball bearings from standpoint of materials, torque, load ratings, static load capacity and isoelasticity. Dimensions are tabulated for such types as single-row radial, angular contact, flanged and torque tube. Fafnir Bearing Co, 37 Booth St, New Britain, Conn.

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POWER-TRANSMISSION COMPONENTS—Catalog 760, 116 pp. Carries ARSCM hp ratings and other specifications of roller and conveyor chains, sprockets and couplings. Photographs and dimensional drawings are included. Diamond Chain Co Inc, 402 Kentucky Ave, Indianapolis 7.

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ROTARY SWITCHES—Catalog, 48 pp. Illustrates and tabulates dimensions of single-deck (shorting and nonshorting) and multiple-deck switches (both shorting

continued on page 79

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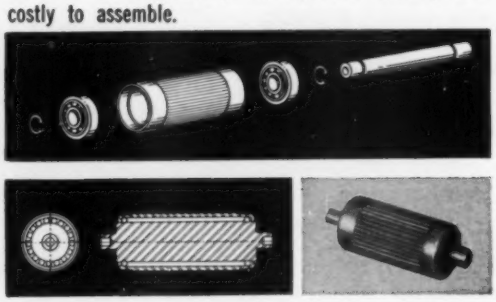

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POPPET-TYPE VALVES—Bulletin 60-2, 6 pp. Table lists model numbers and port sizes of full line of 2-, 3- and 4-way, as well as 4-way, 5-port valves with their air and solenoid pilot operators. Cutaway drawings show construction features, sealing arrangements, poppets and flow pattern. Hoffman Valves Inc, 2360 W Dorothy Lane, Dayton 39, Ohio.

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ROD ENDS AND BEARINGS—Catalog 101, 12 pp. Illustrates and gives dimensions, angle of misalignment and max radial static capacity of male and female rod ends, spherical bearings and control-rod assemblies. Split Ballbearing, Div MPB Inc, Lebanon, NH.

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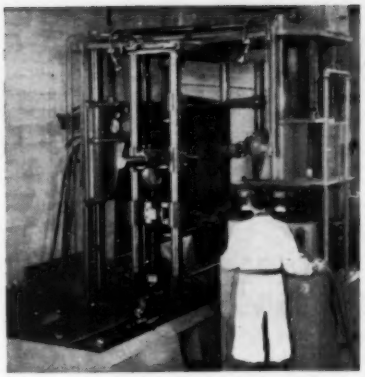
HOLD-BACK CLUTCHES—Catalog, 12 pp. Covers speed and idler factors and dimensional and mounting data on 12 models in bore sizes from 1 1/8 to 12 in. Discusses design features, operation, and selection calculations. Formsprag Co, 23601 Hoover Rd, Warren, Mich.

Circle 355 on Reader Service Card

PLASTIC DIE STEELS—Brochure, approx 20 pp. Explains grade characteristics of steels for plastic-mold applications and tabulates mold properties and heat-

continued on page 81

"Good heavens! I was laid off last June!"



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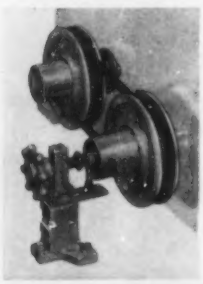

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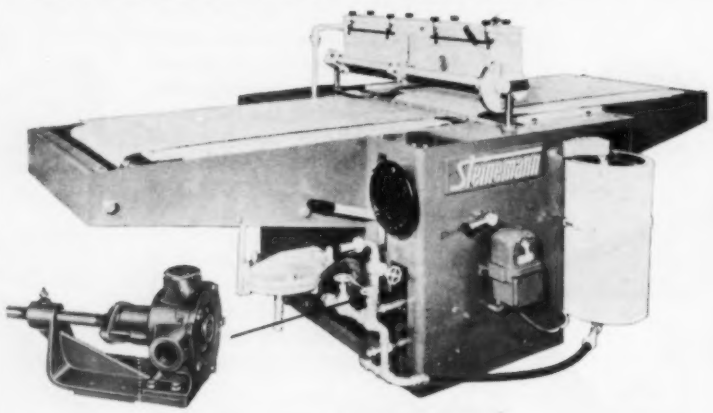

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treating instructions. Compositions and tempering temperatures are outlined for six types. Vanadium-Alloys Steel Co, Latrobe, Penna.

Circle 356 on Reader Service Card

BLIND RIVETS—Bulletin TCL-160, 12 pp. Contains specifications of plugged (structural) and hollow (nonstructural) types available in aluminum, mild steel and monel. Selection data covers material thickness and recommended drill-hole sizes. Cherry Rivet Div, Townsend Co, Box 2157-Z, Santa Ana, Calif.

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Y AND START-UP STRAINERS—Catalog 6008, 12 pp. Outlines available body materials, end connections, pressure ratings, sizes, and pressure-temperature limits. Also tabulates total free-hole areas for more than 300 available screens. Leslie Co, Strainer Section, 80 Delafield Ave, Lyndhurst, NJ.

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DRY BATTERIES—Manual, 108 pp. Describes and illustrates 1¼ to 510-v types. Curves for estimating battery performance show service life of each when discharged continuously or for 4 hr a day at 70 F. Terminal illustrations are included. Price: $1, but free to design engineers. Burgess Battery Co, Freeport, Ill.

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CONTROL AND INDICATING COMPONENTS—Folder, 6 pp. Illustrates and outlines specifications of representative precision mechanical components, counters and indicators, timing and programming devices, electromechanical devices and servo packages. Bowmar Instrument Corp, 8000 Bluffton Rd, Fort Wayne, Ind.

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METALS INFORMATION—Brochure, 8 pp. Explains ASM's biweekly digests of up-to-date literature in the metals engineering field. Also describes automated, computer-based metallurgical-literature-searching service. American Society for Metals, Metals Park, Novelty, Ohio.

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EXPANSION INSERTS—Bulletin P-101, 2 pp. Traces installation instructions, dimensions and prices. Explains how insert forms permanent brass threads in plastics after molding or in other parent materials. Phelps Mfg Div, Heli-Coil Corp, Danbury, Conn.

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ALUMINUM FORGING—Booklet, 20 pp. Reviews production of all types of aluminum forgings, including precision, conventional, no-draft, blocker-type, hand, smith and impact, as well as rolled rings and forged fittings. Tabulates alloy mechanical properties for die forgings. Harvey Aluminum, 19200 S Western Ave, Torrance, Calif.

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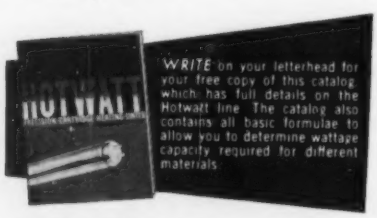

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A

Albion Industries, Inc. 81
Anaconda Metal Hose Co. 36
Automotive & Aircraft Div., American Chain & Cable Co., Inc. .. 38

B

Barco Mfg. Co. 76
Berry Hydraulics Div., Oliver Tyrone Corp. 70
Bound Brook Bearing Corp. of America ..... 3rd Cover
Bruning Co., Inc., Charles 35
Burndy Corp. 23

C

Chicago Rawhide Mfg. Co. ..... 4th Cover

D

Di-Acro Corp. 65
Dodge Mfg. Corp. 22
Dow Corning Corp. 2
Dow Metal Products Co., Div. Dow Chemical Co. 64-65
Dura Corp., Automotive Div. 5

E

Eaton Mfg. Co., Dynamatic Div. 67
Erlez Mfg. Co. 66

F

Fairchild Engine & Airplane Corp., Stratos Div. 74
Fairfield Mfg. Co., Inc. 28
Federal-Mogul Div., Federal-Mogul-Bower Bearings, Inc. 27

G

Garlock, Inc. 21
General Electric Co., Miniature Lamp Dept. 68

H

Hartford Steel Ball Co. 78
Hoover Ball & Bearing Co., Bearing Div. 33
Hotwatt, Inc. 82

I

Industrial Electronic Engineers, Inc. .. 70

L

Link-Belt Co. 11
Little Giant Pump Co., Div., Little Giant Corp. 76

M

McGill Mfg. Co., Inc., Bearing Div. ... 13
McGraw-Hill Book Co., Inc. 75
MacLean-Fogg Lock Nut Co. 71
Minnesota Mining & Mfg. Co., Adhesives, Coatings, Sealers Div. .. 26
Morse Chain Co., A Borg-Warner Industry 18-19
Mueller Brass Co. 69

N

Neise, Inc., Karl A. 70

O

Ohio Knife Co. 79

P

Perkins Machine & Gear Co. 77
Plastron Corp. 80
Post Co., Frederick 29

R

Robbins & Myers, Inc. 7
Ross Operating Valve Co. ..... 2nd Cover
Russell, Burdsall & Ward Bolt & Nut Co. 10

S

Sinko Mfg. & Tool Co. 76
Speed Selector, Inc. 80
Square D. Co. 31
Stratos Div., Fairchild Engine & Airplane Corp. 74
Stromberg-Carlson—San Diego, Div., General Dynamics Corp. 14

T

Thomson Industries, Inc. 73
Tuthill Pump Co. 34

U

Union Steel Products Co. 32

V

Valcor Engineering Corp. 72
Viking Pump Co. 80
Vulcan Div., Reeves Bros., Inc. 78

W

Wagner Electric Corp. 30
Wall Colmonoy Corp. 72

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Employment Opportunities 80

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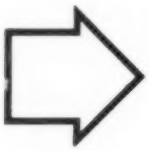

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Properties of steel tapes and how they can be designed to transfer loads.

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Eleven special types that vary fluid flow in any nonlinear manner desired.

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Useful tabular aids based on chance relationships between scales.

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2	22	42	62	82	102	122	142	162	182	202	222	242	262	282	302	317	332	347	362	377
3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	318	333	348	363	378
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	319	334	349	364	379
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	320	335	350	365	380
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	321	336	351	366	381
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	322	337	352	367	382
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	323	338	353	368	383
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	324	339	354	369	384
10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	325	340	355	370	385
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	326	341	356	371	386
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	327	342	357	372	387
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	328	343	358	373	388
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	329	344	359	374	389
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	330	345	360	375	390
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297						
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300						

REPRINTS

P68	P69	P70	P71	P72	P73	P74	P75	P76	P77	P78	P79
580	581	582	583	584	585	586	587	588	589	590	591

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RESEARCH & TEST EQUIPMENT
332—Load Indicator
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311—Silicone Encapsulating Resin

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304—Thick Section Cure in 24 Hours

POWER TRANSMISSION
306—Self-aligning Coupling
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306—Miniature Shaft Coupling
313—Driver Pulleys
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MECHANICAL PARTS
307—Cable Clamping Connector
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322—Rotary Indexing Table
326—Alumnium Knobs and Hubs
330—Footswitches

FASTENING AND JOINING
301—Vibration Damping Tape
307—Cable Clamping Connector

MOTORS, ENGINES AND CONTROLS
315—Speed Sensing Switches
318—Battery-powered Motor
323—Size 5 Servomotor
331—Wound Rotor Motors

ELECTRICAL, ELECTRONIC COMPONENTS
308—Low Pressure Sensing Switch
310—In-line Digital Readout
312—Electronic Control Meter
315—Speed Sensing Switches
319—Elapsed Time Indicator
327—600-v Relays
328—Tiny Pushbutton Switch
329—Modular-type Pushbutton

HYDRAULIC, PNEUMATIC EQUIPMENT
303—Potentiometric-type Transducer
305—Revolving Joint
309—Multiple-unit Control Valves
317—Bronze Ball Valve
321—Power Positioner
324—Single Solenoid 4-way Valve
325—Miniature, Heavy-duty Cylinder

366—Metals Information, 8 pp, American Society for Metals
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POWER TRANSMISSION
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ELECTRICAL, ELECTRONIC COMPONENTS
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3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	318	333	348	363	378
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	319	334	349	364	379
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	320	335	350	365	380
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	321	336	351	366	381
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	322	337	352	367	382
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	323	338	353	368	383
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	324	339	354	369	384
10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	325	340	355	370	385
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	326	341	356	371	386
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	327	342	357	372	387
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	328	343	358	373	388
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	329	344	359	374	389
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	330	345	360	375	390
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297						
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300						

REPRINTS

P68	P69	P70	P71	P72	P73	P74	P75	P76	P77	P78	P79
580	581	582	583	584	585	586	587	588	589	590	591

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3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	318	333	348	363	378
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	319	334	349	364	379
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	320	335	350	365	380
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	321	336	351	366	381
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	322	337	352	367	382
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	323	338	353	368	383
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	324	339	354	369	384
10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	325	340	355	370	385
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	326	341	356	371	386
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	327	342	357	372	387
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	328	343	358	373	388
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	329	344	359	374	389
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	330	345	360	375	390
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297						
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300						

REPRINTS

P68	P69	P70	P71	P72	P73	P74	P75	P76	P77	P78	P79
580	581	582	583	584	585	586	587	588	589	590	591

*MULTIPLE Key No.	PRODUCT ADS Specific Product

INDEX OF PRODUCTS ADVERTISED IN THIS ISSUE

A

Actuators
- Electrical 5
- Mechanical 5

Adhesives 26

B

Balls 78

Bearing Materials 69

Bearings
- Ball 13, 33, 73, 78
- Needle 13
- Roller 13
- Self-Lubricating ..... 3rd Cover
- Sleeve 27

Belts, Timing 18–19

Books 75

Brakes
- Electric 67

Brazing
- Alloys 72

Bushings 27, 73

C

Casters 81

Chains
- Conveyor 18–19
- Roller 18–19
- Silent 18–19

Clad Metals 79

Clutches
- Electrical 67
- Mechanical 18–19

Coatings 80

Connectors
- Electrical 23

Controls
- Mechanical 38

Conveyors 66

Couplings
- Mechanical 18–19

D

Digital Displays 70

Drafting
- Machines 29, 35
- Supplies 35

Drives
- Variable Speed 11, 74, 80

E

Extrusions
- Metallic 64-65

F

Fabrics, Coated 78

Fastening Methods 10

Fittings, Hose, Pipe and Tube 36

Forgings 69

G

Gaskets 21

Gear Boxes 74

Gears 28, 77

H

Hard Surfacing 72

Heating Units 82

Hose and Tubing 36

J

Joints
- Swing and Swivel 76

L

Lamps, Indicator 68

Lubricants 2

M

Magnesium Alloys 64-65

Magnetic Materials 66

Moldings
- Plastics (see Plastic Parts)

Motors, A-C
- Fractional 7, 30
- Integral 30
- Sub-Fractional 7

Motors, D-C
- Fractional 7, 30
- Integral 30
- Sub-Fractional 7

Mountings 22

N

Nuts 71

P

Packings 21

Plastic Parts 76

Plastics 80

Plastics Fabricated 76

Press Brakes 65

Production Machines and Processes 65, 66

Pumps
- Liquid 34, 70, 76, 80

R

Recorders 14

Relays 31

Reproduction Equipment 35

Reproduction Supplies 29, 35

Revolving Joints (see Joints, Swing and Swivel)

S

Seals ..... 4th Cover, 21

Sheaves 80

Silicones 2

Spacers 27

Specialty Fasteners (Pipe Hangers, Special Cold Headed Parts, etc.) 10, 71

Speed Increasers and Reducers 18–19

Springs 70

T

Transmissions 74

Tubing
- Flexible Metal 36

V

Valves
- Air ..... 2nd Cover
- Solenoid ..... 2nd Cover, 72

W

Washers 27

Wear Materials 79

Wire 32

After reading the advertisements classified above . . . MORE DETAILED INFORMATION about these products can be obtained by using the attached READER SERVICE CARD.

86

Circle 202 Reader Service Card →

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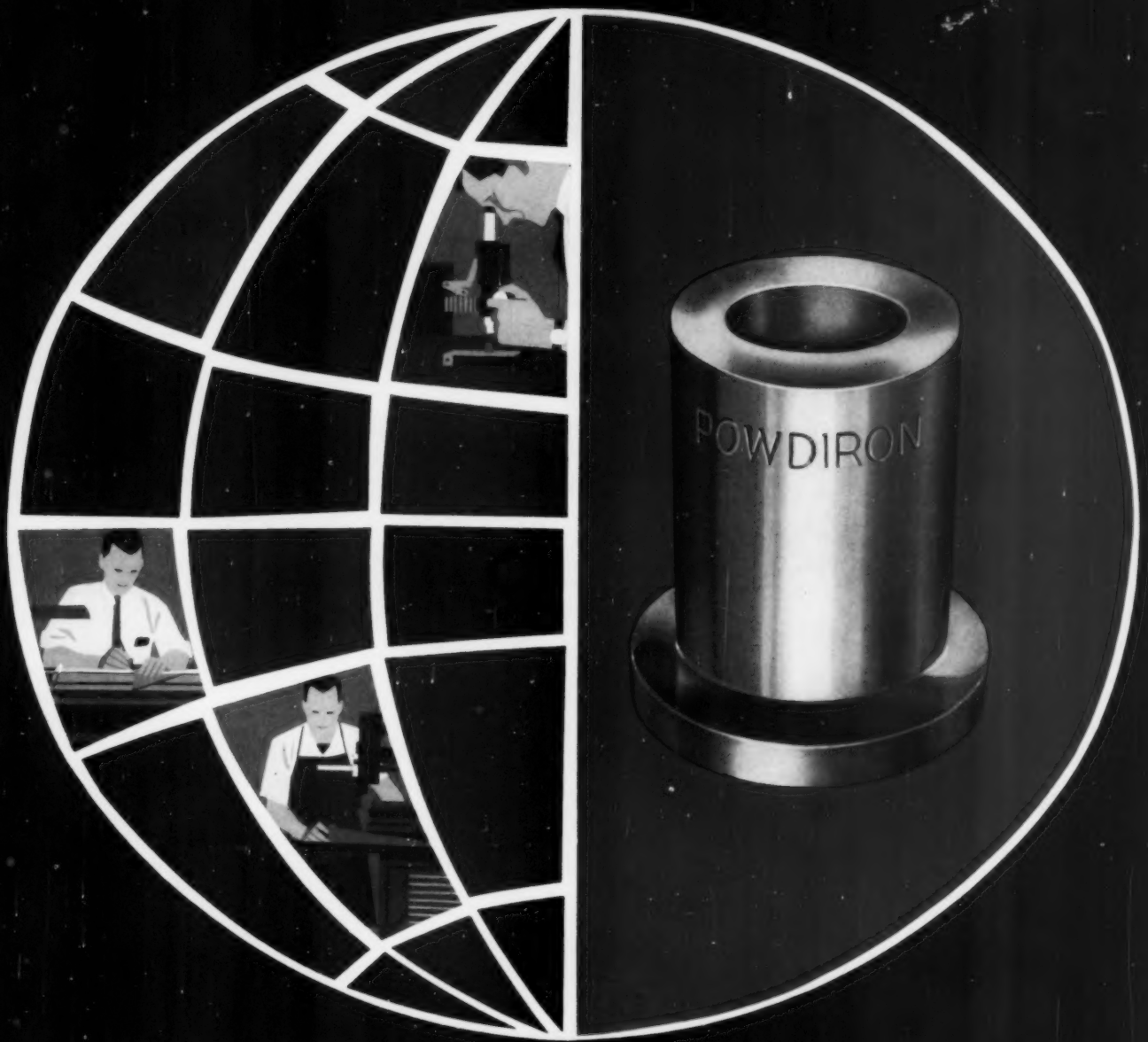

New Alliance–New Processes–NEW ECONOMY

From Bound Brook's newly-formed association with the world-wide organization of Birfield Limited, comes the new Ferrocite process—making possible economies of operation never before available in self-lubricated iron bearings of Bound Brook quality. The high standards of Powdiron® quality have been retained, but the resultant economies make Bound Brook your best buy in iron bearings. The next time your specs call for self-lubricated iron bearings, it will pay you to call Bound Brook.

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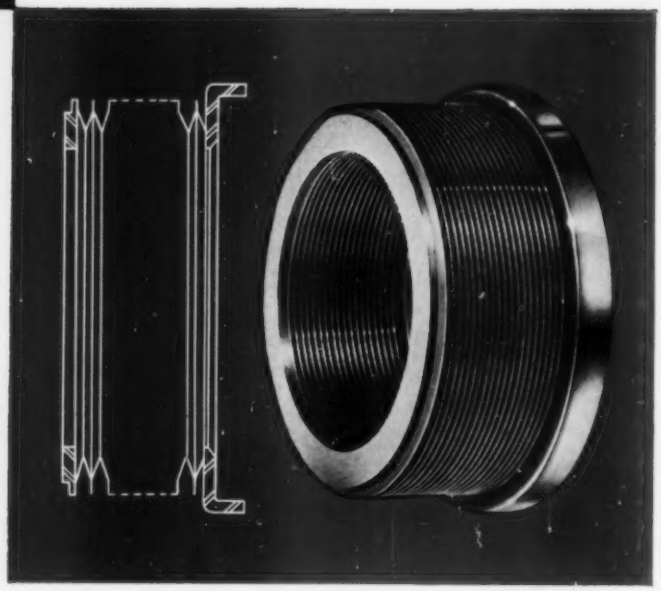
CORPORATION OF AMERICA
A BIRFIELD COMPANY
Pioneer in Powder Metallurgy Bearings and Parts • Plants at Bound Brook, N.J. and Sturgis, Mich.

C/R DESIGN NOTES

How C/R's New Metal Bellows Seal Meets Seemingly Impossible Operating Conditions



Operating Ranges

Temperature	−400° to 1000° F.
Pressure	500 psi
R.P.M.	80,000 plus

These known operating ranges indicate the function of this seal. It is designed for applications where temperatures and mediums to be sealed forbid the use of any organic materials. Typically, these applications include fuel pumps, compressor power units and turbine starters characteristic in rockets and missiles. Other applications include mechanisms which are exposed to a high level of radioactivity.

Design Advantages

The C/R metal bellows seal consists of a metal bellows — a welded homogeneous unit which is secured at one end — and a carrier ring in which the sealing face is mounted. The seal does not contact the shaft. It is stationary, and the only rubbing surfaces are the sealing face and mating ring. These surfaces are precision lapped to provide a positive seal with minimum friction. At any given pressure, the seal can be designed to maintain proper and constantly effective face loads. It orients immediately to run-out and will resist any torques it is subjected to in operation. The design has high end-play tolerance: Chicago Rawhide engineers have deflected a bellows .100 in. for three million cycles at 1750 cpm and at a temperature of 500° F. with no adverse effects.

A further advantage is relatively light weight and compactness. The C/R metal bellows seal can be designed for minimum axial and radial space. Axially, complete seals can be produced within a ¼ in. cross-section. Radially, dimensions are comparable with conventional end face seals.

The C/R metal bellows seal can also be designed with an extremely low coefficient of expansion. The importance of this factor becomes apparent with the fact that in many applications the operating temperature may change hundreds of degrees in a very few seconds.

Mediums To Be Sealed

Virtually any known liquid or gas may be positively sealed with this design, depending upon duration or service life. From a practical viewpoint, the C/R metal bellows seal is the best design for the sealing of cryogenic and high-energy fuels such as LOX, hydrogen peroxide, fluorine and other missile and rocket propellants.

Where possible, lubrication of the two sealing faces is desirable to prolong service life. However, the medium being sealed commonly acts as the lubricant and may be merely hot gas.

Materials

Sealing faces and mating rings for the C/R metal bellows seal are available in a variety of materials including carbons, carbides, ceramics and various alloyed metals for both high temperature and corrosion resistance. The bellows can be furnished in any of several metals and alloys such as stainless steel, Monel, Inconel X, Ni-Span C and other special alloy steels.

Consult C/R Engineers

Each application for the C/R metal bellows seal is essentially a custom-design and an intimate knowledge of all conditions to be encountered must be known by Chicago Rawhide engineers to produce the correct combination of properties in the seal. Then, whether you require five, fifty or five thousand seals, Chicago Rawhide will design and produce the correct seal to solve your problem.

Helpful Design Data:

We will gladly furnish you with a design guide and space envelope data concerning the C/R Metal Bellows Seal. Just write for Bulletin MBS-1 on your company letterhead.

CHICAGO RAWHIDE MANUFACTURING COMPANY

1237 Elston Avenue • Chicago 22, Illinois

Offices in 55 principal cities

In Canada: Chicago Rawhide Mfg. Co. of Canada, Ltd., Brantford, Ontario

Export Sales: Geon International Corp., Great Neck, New York

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